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*REPORT OF SURVEY CONDUCTED AT*

**HAMILTON STANDARD  
ELECTRONIC MANUFACTURING CENTER**

FARMINGTON, CT

*OCTOBER 1993*

**BEST MANUFACTURING PRACTICES**



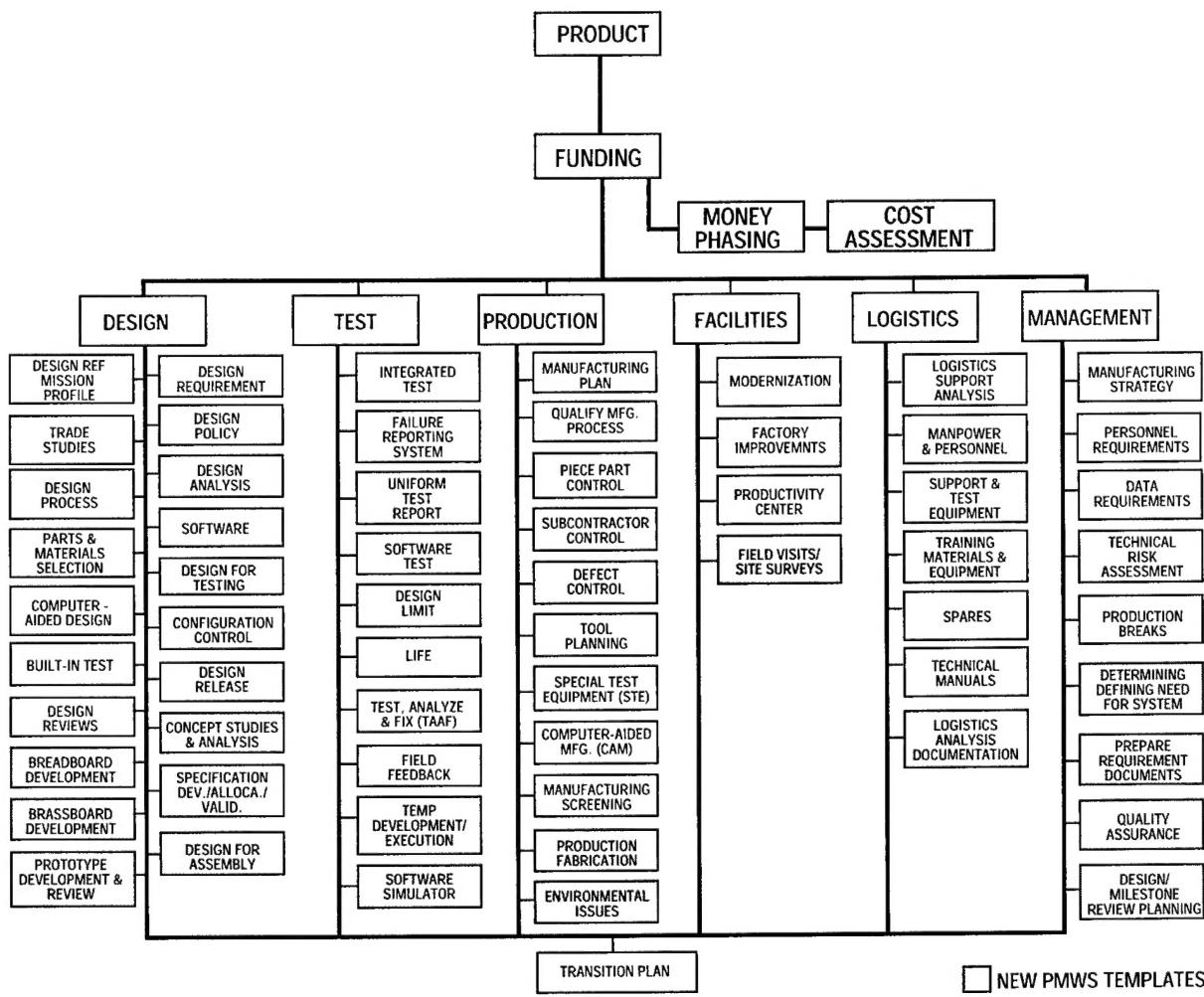
*Center of Excellence for Best Manufacturing Practices*

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## “CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION”



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# SECTION 1

## EXECUTIVE SUMMARY

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### 1.1 BACKGROUND

The Navy's Best Manufacturing Practices (BMP) program team conducted a survey at the Hamilton Standard Electronic Manufacturing Center (HSEMC) located in Farmington, Connecticut the week of 4-8 October 1993. The purpose of the HSEMC survey was to review and document its best practices and investigate any potential industry-wide problems. The BMP program will use this documentation as an initial step in a voluntary technology sharing process among industry, government, and academia.

The Electronic Manufacturing Center in Farmington, Connecticut is a functional unit of the Hamilton Standard division of United Technologies Corporation. This facility covers over 160,000 square feet and supports almost 400 employees. Operations include production of electronic systems for flight controls for the Black Hawk helicopter, CH53/MH53 helicopter and Seahawk helicopter. In addition, HSEMC produces electronics for the data systems for the F/A-18, C-17, and F-15 aircraft, as well as the Apache and Comanche helicopters. Electronic systems are also included in the missile engine controls for the Harpoon missile. HSEMC also produces precision sensors for military aircraft, helicopters, and missiles.

The HSEMC presented the BMP program survey team an outstanding example of a successful business comeback. This facility rebounded from an unfavorable situation to become a high-quality producer of electronics for flight controls and data management systems for several key military aircraft and missile platforms. In the late 1980s, adverse conditions prompted HSEMC to re-evaluate its way of doing business and the quality of its product. Internal and external feedback highlighted the need for widespread changes in what the company was producing as well as its means of production. This introspective analysis at HSEMC resulted in basic shifts of management philosophy as well as far reaching trends on the production floor.

There are two critical elements in the turnaround from reactionary to solution-oriented operations at the Farmington, Connecticut facility that were evident in all presentations during the BMP survey. Those elements include communication and the unique application of common practices to HSEMC's specific operation.

Good communication in any company has become a basic ingredient for success; however, at HSEMC, communication is not just basic but a key reason for its present

situation. Management and associates maintain an active, free-flowing association using common tools such as Total Quality Management or less common ones such as the establishment of an all salary workforce. Each associate is aware of his or her individual place in the overall company process. Complex data is visually presented in simple forms such as in HSEMC's singular use of arachnoid charts.

HSEMC also individualizes many common practices to achieve maximum results. These practices include areas such as continuous improvement efforts and metric alignment/flowdown. By internalizing the precepts of processes such as agile manufacturing and specializing them to HSEMC's operation, the company has established itself as a forerunner in several production areas. Specifically, the BMP survey team considered HSEMC to have one of the best continuous flow manufacturing operations ever documented.

The Hamilton Standard Electronic Manufacturing Center provides any company with a roadmap for applying good management techniques and sound business practices – and ensuring its successful application by strong support from highly motivated and trained personnel. This effort is providing HSEMC with an environment of opportunity to expand its share of the global marketplace. The company is well on the road to world class manufacturing through strong communication procedures and individualized application of common practices.

### 1.2 BEST PRACTICES

The best practices documented at HSEMC are detailed in this report. These topics include:

Item	Page
Design to Cost	7
Manufacturing Technology Insertion	8

The design to cost initiative at the HSEMC is a major element of the overall product design and development life cycle management process initiated in the proposal stage.

The HSEMC instituted several process changes to ensure the timely introduction of Manufacturing Technology Insertion to address advanced packaging, environmental, and cost competitive technologies needs for future electronics business.

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Item	Page	Item	Page
<b>Concurrent Engineering</b>	<b>8</b>	<b>Source Inspection Laptop Kit</b>	<b>12</b>
Concurrent engineering at HSEMC is applied through an integrated product development process to connect initial product concept, design, and related processes to manufacturing and support.		The Source Inspection Laptop Kit at HSEMC is a computerized system designed to eliminate inspecting incoming components for items such as conformity and verification of correct engineering configuration.	
<b>Design Review for Producibility</b>	<b>9</b>	<b>Supplier Point-of-Use</b>	<b>12</b>
The HSEMC has developed a design review program in support of its producibility efforts and integrated product development cycle. These reviews are conducted by experts from the design, test, and production departments.		The Supplier Point-of-Use technique provides for the supplier delivering quality parts directly to the point of usage on the factory floor.	
<b>Design for Manufacturability</b>	<b>9</b>	<b>Certified Supplier Program</b>	<b>13</b>
Producibility and manufacturability are interchangeable terms at HSEMC, and are primarily focused on the design and development of printed wiring board assemblies, chassis, and complex ICs. A producibility assurance group co-located with engineering is a keystone to the development of producibility guidelines resulting in substantial cycle time reductions, and reduction in scrap, rework, and repair.		The Hamilton Standard Manufacturing Center implemented its Supplier Certification Program in April of 1993 with objectives to identify suppliers with excellent performance and process controls and assist suppliers in getting their processes under control through training and process reviews.	
<b>Board Test</b>	<b>10</b>	<b>Environmental Program</b>	<b>13</b>
HSEMC conducted informal industrial surveys on board testing and as a result, realized significant cost and time savings by replacing functional board testing with in-circuit testing.		The HSEMC has developed an environmental program designed to keep it ahead of quickly changing regulations and to promote the proper use of hazardous materials for the benefit of the community.	
<b>Automatic Data Collection</b>	<b>10</b>	<b>Inventory and Asset Management</b>	<b>14</b>
The HSEMC has implemented an automatic data collection system that makes test results and failure data available for factory-wide review.		Hamilton Standard EMC has pursued an aggressive inventory reduction program since 1991, and inventory and asset management has become the job of every HSEMC associate.	
<b>Continuous Flow Manufacturing</b>	<b>11</b>	<b>Process Control Strategy</b>	<b>14</b>
When HSEMC introduced continuous flow manufacturing into its production line, it eliminated many problems such as a push system versus pull system.		A unique video delivery training method has been implemented at HSEMC to teach process control.	
<b>Process Analysis for Manufacturability</b>	<b>11</b>	<b>Manufacturing Strategy Process</b>	<b>14</b>
Hamilton Standard applies the Process Analysis for Manufacturability technique at its facility in Farmington, CT to characterize and optimize manufacturing processes.		The HSEMC manufacturing strategy incorporates elements of Agile Manufacturing, the Air Force's Lean Manufacturing initiative, and other best business practices.	
		<b>Customer Satisfaction</b>	<b>15</b>
		The HSEMC employs a well-developed and implemented process for satisfying customer expectations and requirements. Its goal is to consistently meet or exceed customer – both internal and external – expectations and requirements.	

Item	Page	Item	Page
<b>External Involvement for Manufacturing Research and Development</b>	<b>16</b>	<b>Metric Alignment/Flowdown</b>	<b>20</b>
Hamilton Standard has found that there are many benefits to collaborative research and development efforts with other industrial and government partners in solving industry-prevalent problems.		Each Hamilton Standard business unit, including the Farmington, CT Electronic Manufacturing Center, has developed annual objectives and implementation plans that focus on achieving divisional level objectives and satisfying individual customer needs.	
<b>Benchmarking Process</b>	<b>16</b>	<b>1.3 INFORMATION</b>	
Benchmarking other best industry practices is considered by the Hamilton Standard Electronic Manufacturing Center to provide the basis for its journey in continuous improvement.		The BMP survey team documented the following information items at HSEMC:	
<b>Finance Office Kaizen</b>	<b>17</b>	<b>Design for Environment</b>	<b>23</b>
At Hamilton Standard, continuous improvement has been integrated not only on the factory floor, but also in offices – the finance section used the Kaizen method to revamp its office area.		To comply with the environmental requirements imposed by federal, state, and local governments, the HSEMC has instituted a policy for hazardous materials reduction to meet or exceed regulations or suggested federal Environmental Protection Agency goals.	
<b>Continuous Improvement</b>	<b>17</b>	<b>Laser Marking System</b>	<b>23</b>
The need for a fundamental change in 1987 at Hamilton Standard Electronic Manufacturing Center in how business was conducted – and ultimately the survival of the company as a corporate entity – prompted it to embark on a new management philosophy.		Hamilton Standard Electronic Manufacturing Center's previous method of creating nameplates was a manual, expensive, unreliable, and time-consuming process. Therefore, a cross-functional team selected by HS selected a laser marking system to replace the old system.	
<b>Work Environment</b>	<b>18</b>	<b>Environmental Stress Screening Testing</b>	<b>23</b>
In the 1990s, the HSEMC focuses on people, values, and their continued development as the most important force in the company.		Hamilton Standard has addressed reducing unneeded processes in the environmental stress screening structure to gain cost savings and optimize unit field life.	
<b>All Salary Workforce</b>	<b>19</b>	<b>Factory Improvements</b>	<b>24</b>
HSEMC decided to eliminate the traditional compensation system and implement a single compensation system for all associates to unify the workforce, break down invisible barriers to communication, simplify systems, reduce administration costs, and enhance organizational agility.		In an effort to reduce cycle time and improve responsiveness to its customers, HSEMC initiated a strategy to improve its factory. At the heart of this strategy is a Continuous Flow Manufacturing technique and a multi-faceted approach that has changed HSEMC's entire organization.	
<b>Communication Process</b>	<b>19</b>	<b>Health and Safety</b>	<b>24</b>
Associates at HSEMC understand that to enhance the atmosphere of the work place, individuals need to improve communication skills. To accomplish this goal, Hamilton Standard developed a communication process to facilitate consistency of understanding.		HSEMC uses many techniques to maintain a successful health and safety program. These efforts have had favorable results in reducing lost time and other accidents.	

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Item	Page	Item	Page		
<b>Training</b>	<b>25</b>	<b>Requirement Conflicts</b>	<b>27</b>		
The Hamilton Standard Electronic Manufacturing Center's philosophy of continuous improvement is strongly supported by a comprehensive, broad-based associate training program.		Environmental Protection Agency versus MIL-SPECs conflicts are becoming more numerous.			
<b>Recognition and Involvement Program</b>	<b>25</b>	<b>MIL-SPEC Component Availability</b>	<b>27</b>		
The Hamilton Standard Electronic Manufacturing Center has a number of programs for recognizing individual and team performance, and many programs that provide an opportunity for associates to get involved and represent the company in the local community.		The lack of readily available MIL-SPEC parts artificially increases product costs and lengthens development and manufacturing cycle times.			
<b>Labor Reporting 26</b>		<b>Customer Scheduling Perturbations</b>	<b>27</b>		
The labor reporting structure at Hamilton Standard has become a labor-intensive, non-value added task targeted for elimination. HSEMC will become the pilot site to test the idea that efficiency and productivity can be enhanced by tracking cycle time and rework hours.		As companies reduce inventory, they face problems delivering products to the customer that had not been scheduled because of the long lead times required for certain components.			
<b>1.4 PROBLEM AREAS</b>					
The Hamilton Standard Electronic Manufacturing Center identified the following areas in Design and Production as potential industry-wide problems that should be addressed by industry and government for possible avenues of solution.		<b>Accounting Systems</b>	<b>27</b>		
<b>Product Development Cycle Compression</b>	<b>27</b>	Accounting practices by many U.S. firms are still applied that result in excessive inventory as a result of the way overhead is accounted to direct hours charged on the factory floor.			
New problems are emerging due to activities throughout the product development processes being compressed and executed in parallel.		<b>Part Marking Removal with New Cleaning Processes</b>	<b>27</b>		
<b>Extended Product Life Cycle</b>	<b>27</b>	As new cleaning processes are implemented to eliminate the use of ozone depleting chemicals, a problem has arisen with the new processes removing the part markings.			
The changes in DOD to extend current defense equipment life will increase parts obsolescence. Suppliers are faced with the choices of maintaining a life-of-type stock of obsolete parts, procuring the parts through after-market vendors at high prices, or redesigning and requalifying the new part at extremely high costs.		<b>1.5 ACTIVITY POINT OF CONTACT</b>			
For more information on the best practices, information items, or problem areas identified in this report, contact:					
Mr. Steve Pavlech Manager, Technology Planning and Development United Technologies Hamilton Standard Electronic Manufacturing Center One Hamilton Road Windsor Locks, Connecticut 06096 Phone: (203) 654-2491					

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## **SECTION 2**

### **INTRODUCTION**

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#### **2.1 SCOPE**

The purpose of the Best Manufacturing Practices (BMP) survey conducted at the Hamilton Standard Electronic Manufacturing Center (HSEMC) in Farmington, Connecticut was to identify best practices, review problems, and document the results. The intent is to extend the use of progressive management techniques as well as high technology equipment and processes throughout industry and government facilities. The ultimate goal of the BMP program is to strengthen the U.S. industrial base and reduce the cost of defense systems by solving manufacturing problems and improving quality and reliability.

A team of engineers accepted an invitation from the HSEMC to review the processes and techniques used at the hotel located in Farmington, CT. Potential industry-wide problems were also reviewed and documented. The review was conducted in Farmington, CT on 4 October through 8 October 1993 by the team identified in Appendix B of this report.

The results of BMP surveys are entered into a database for dissemination through a central computer network (see Appendix C). The actual exchange of detailed data will be between companies at their discretion. The results of this survey should not be used to rate the Hamilton Standard Electronic Manufacturing Center with other commercial companies, government activities, or defense contractors. The survey results have no bearing on one facility's performance over another's. The documentation in BMP reports is not intended to be all inclusive of the activity's best practices. Only selected non-proprietary practices are reviewed and documented by the BMP survey team.

#### **2.2 SURVEY PROCESS**

This survey was performed under the general survey guidelines established by the Department of the Navy. The survey concentrated on the functional areas of design, test, production, facilities, logistics, and management. The team evaluated the Hamilton Standard Electronic Manufacturing Center's policies, practices, and strategies in these areas.

Furthermore, individual practices reviewed were categorized as they relate to the critical path templates of DOD 4245.7-M, "Transition from Development to Production." The HSEMC identified potential best practices and industry-wide problems. These practices and other areas of interest were discussed, reviewed, and documented for distribution throughout the U.S. industrial base.

The format for this survey consisted of formal briefings and discussions on best practices and problems. Time was spent at the Hamilton Standard Electronic Manufacturing Center reviewing practices, processes, and equipment. In-depth discussions were conducted to better understand and document the identified practices and problems.

Demonstrated industry-wide problems identified during the Best Manufacturing Practices surveys may be referred to one of the Navy Manufacturing Technology Centers of Excellence. They are identified in Appendix D.

#### **2.3 ACKNOWLEDGMENTS**

Special thanks are due to all the people at the Hamilton Standard Electronic Manufacturing Center whose participation made this survey possible. In particular, the BMP program acknowledges the special efforts of Mr. Steve Pavlech and Mr. Tony Rice for enabling this survey to occur.

## SECTION 3

### ***BEST PRACTICES***

### **3.1 DESIGN**

## **DESIGN POLICY**

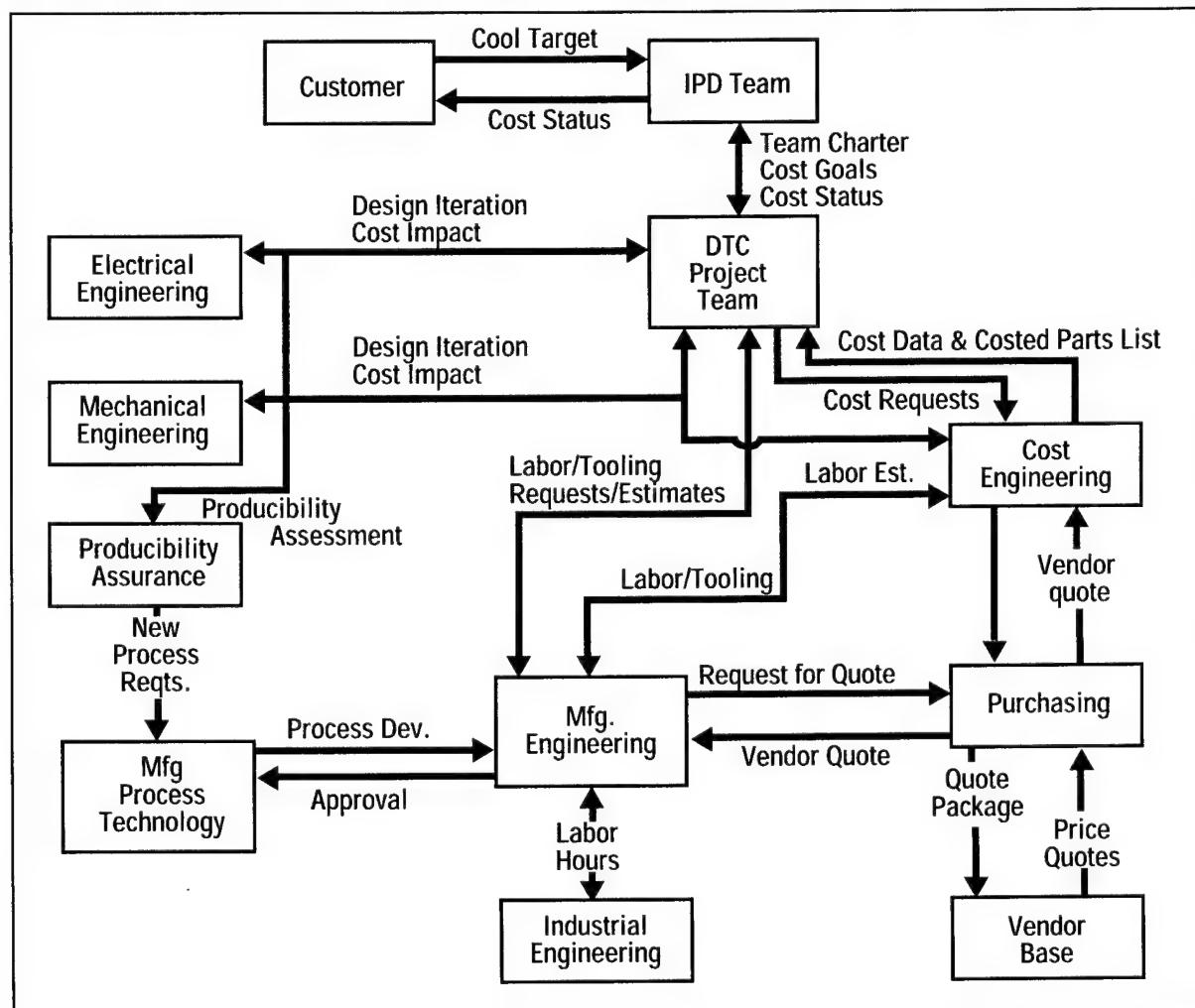
## Design to Cost Information

The design to cost (DTC) initiative at the HSEMC is a major element of the overall product design and development life cycle management process initiated in the proposal stage. This DTC process results in the establishment of product target cost goals that meet customer expectations

and is broken down into sub-system, sub-assembly, and piece part labor and material goals.

DTC is an iterative process that steps through a cadre of legacy data, design criteria, producibility guidelines, reliability information, and other elements to establish targets. The process (Figure 3-1) encompasses the setting of individual cost targets; defining a process that will achieve the targets; implementing and modifying the defined process; analyzing data collected; and modifying the analyses.

Functional responsibilities are categorized for the DTC project team and include cost tradeoff initiator, design,



**FIGURE 3-1. DESIGN TO COST PROJECT TEAM IMPLEMENTATION PROCESS**

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electrical components engineering, cost engineering, purchasing, Integrated Product Development (IPD) team, producibility assurance, manufacturing engineering, systems design, and development engineering. This well-defined process and assigned responsibilities collectively result in customer satisfaction and a cost-effective design. The DTC cost over target average for 19 major programs at HSEMC is only .04%.

## Manufacturing Technology Insertion

The Hamilton Standard Electronic Manufacturing Center (HSEMC) instituted several process changes for Manufacturing Technology Insertion to address advanced packaging, environmental, and cost competitive technologies needs for future electronics business.

Several factors necessitated improvement in the previous process. Technology selection was primarily an engineering process, and a manufacturing department buy-in did not always occur because of conflicting goals. There was also no manufacturing group dedicated to new technology process development. Delays resulted from unplanned and difficult to approve manufacturing resources and capital. Manufacturing capability was consequently seldom available in time to initiate new product development. Production implementation was often unsuccessful due to insufficient understanding of the risks and inadequate allocation of resources.

Hamilton Standard's Manufacturing Technology Insertion process improvements included formation of a dedicated manufacturing technology group and documented manufacturing technology insertion process, facilitated by use of detailed flowcharts for benchmarking and continuous improvement. These new process steps included:

- Establishing manufacturing development projects to provide estimated development costs, estimated capital costs, project schedules, and risk levels.
- Demonstrating process feasibility and identifying to produce equipment requirements, equipment costs, and risk levels.
- Equipment acquisition for quality equipment and committed suppliers.
- Developing the manufacturing procedures to provide a robust process ( $C_{pk} \geq 1.3$ ) and design guidelines. This step transitions the process to production with full documentation details and process owner transfer.

Process improvement teams engineers and manufacturing associates to establish each business unit's technology insertion schedule used as a tool for resource, capital, and facility planning to improve time to market. An improved

planning and development process facilitates risk management and allows manufacturing capability to be in place in time for new product development. Cross functional involvement in the entire process results in buy-in and commitment throughout the organization.

## DESIGN PROCESS

### Concurrent Engineering

Concurrent engineering at HSEMC is applied through an IPD process to connect initial product concept, design, and related processes to manufacturing and support. IPD represents a teaming arrangement that includes team members from all disciplines participating in influencing products throughout the development cycle to production and support. It is implemented through detailed procedures and guidelines that provide a structured methodology for the formation, function, and operation of the process as a whole as well as for each IPD team.

IPD objectives include achieving customer satisfaction and improved product quality and yield; minimizing total cycle time, cost of design, development and manufacture, and total cost of ownership; and improving transition from engineering to manufacture. These objectives are achieved through four phases of IPD including:

- Phase 1 (pre-proposal phase) in which an analysis of customer requirements versus HSEMC capability is performed and during which identified deficiencies are corrected.
- Phase 2 (proposal preparation phase) in which a design concept is finalized and the program plan is prepared for the conduct of the design, development, manufacturing, and support of the product and processes.
- Phase 3 (product/process design and development phase) in which program implementation begins and efforts initiated to ensure the design, processes, and documentation are completed to the customer's satisfaction.
- Phase 4 (product manufacture and deployment) which centers on full scale manufacture, producibility, and yield.

Teaming is a vital element in the IPD methodology at HS. Team organization consists of a Program System Integration Team of manager-level personnel whose key responsibilities are interfacing with the customer, communicating with upper management, chartering and disbanding IPD teams, specifying team leaders, providing IPD team direction, establishing goals, monitoring performance, and providing resources. Under the Program System Integration

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Team, an Integrated Product Development Team is responsible for communication and planning, customer interface, detail design and development, manufacturing definition, design to cost, program asset management, procurement strategy, and the charter and dissolution of project teams. Project teams are multi-disciplined teams who are responsible to the Integrated Product Development Team; are designed to address a specific issue, task, or project phase; define the required resources; and define the task schedule and milestones.

The institution of Integrated Product Development at the HSEMC is providing a concurrent engineering methodology for improving the quality of engineering, transition to production, and manufacturing processes. The Total Quality Management philosophy is evident as the teams interact throughout all phases of the product's life cycle.

## DESIGN REVIEW

### Design Review for Producibility

The HSEMC has developed a design review program in support of its producibility efforts and IPD cycle. These reviews are conducted by experts from the design, test, and production departments. Producibility design rules are implemented in HSEMC's design for test practice and includes lessons learned. These mandatory producibility design rules are implemented for testing ease, diagnostics, reliability, and statistical process control (SPC) compatibility. Design for test subjects included in the producibility design rule encompass test access, test control, test observation, diagnostics, test equipment design, test equipment software, reliability, fault coverage, fault isolation, documentation, and SPC compatibility.

One set of design rules are followed to reduce the number of design books required for adequate design. The six sigma design process target increases test yields and improves design of performance by identifying tolerance variations from parts failure data. Analysis tools are available that allow designers to simulate component parameter distributions with multiple patterns. Automated factory feedback is available to confirm results or to aid new design decisions. Documentation on this process is required to include design reports, programmable array logic equations, engineering unit conversions, connector definitions, software flowcharts, software listings, and input/output address tables.

The design review program is presented in a Guidelines for Electronics Design Review document which outlines mandatory participants for each step. Team members must be experts in the area they are representing with a minimum of five years related experience. Lessons learned from the process are accessible to all associates with a VAX account and are periodically incorporated into the design guide-

lines. The design guideline document is dynamic in nature and therefore is constantly updated to meet the need for improvement.

Standard circuits are also used to reduce development time and to prevent an engineer from reinventing the wheel. These circuits are mandated for use by the Hamilton Standard Circuit document. Variations from the standards must be justified on the basis of performance, cost, or weight.

The use of design rules such as designing for testability, required documentation, and using pre-developed standard circuits provides a very efficient IPD process. More information known early in the process enhances and improves HSEMC's IPD process. The design review program established by Hamilton Standard has improved the yields and lowered its IPD time by involving all phases of the IPD cycle in the design phase.

## DESIGN FOR ASSEMBLY

### Design for Manufacturability

The HSEMC maintains that producibility and manufacturability are interchangeable terms primarily focused on the design and development of printed wiring board assemblies, chassis, and complex ICs. Management policy at the Center to form a producibility assurance group co-located with engineering is a keystone to the development of producibility guidelines resulting in substantial cycle time reductions and reductions in scrap, rework, and repair.

The HSEMC producibility assurance strategy is to assign a full-time manufacturing engineer to the program; create and follow established factory specific design rules for producibility; review total design activities and participate in all trade studies; expand design mechanization and use a common database to expedite preparation of process sheets and tool designs; appraise engineering of new manufacturing process capabilities; and provide lessons learned feedback from operations to design. This strategy is in support of producibility assurance goals of reducing parts count; maximizing use of standard components; maximizing use of rules-based design; maximizing use of standard manufacturing processes and tooling; using 100% surface mount technology (SMT) components on SMT boards; eliminating post wave solder second assembly; expediting engineering to manufacturing transition; and improving testability.

In addition to teaming, a principal means for implementing the producibility strategy and for achieving the goals is HSEMC's Integrated Product Design System (IPDS). Multiple design and manufacturing disciplines are brought together through ECAD VALID application software from CADENCE and MCAD IDEAS application software from

SDRC. IPDS provides the vehicle for executing near real-time, integrated product design data and information. Cycle time reductions of nearly 50% have resulted because the various activities can be performed concurrently rather than sequentially.

### **3.2 TEST**

#### **INTEGRATED TEST**

##### **Board Test**

The Hamilton Standard Electronic Manufacturing Center (HSEMC) conducted informal industrial surveys on board testing and as a result, realized significant cost and time savings by replacing functional board testing with in-circuit testing, as applicable. In-circuit or bed-of-nail testing was determined to be the best method for testing production unit circuit board at Hamilton Standard.

Function verification is now accomplished at the design level and end item level of board development where in-circuit testing verifies component level functionality and manufacturing flaws that may be present. Test development costs have been reduced 300% to 400% (depending on board complexity), and test development cycle times have been reduced 350% to 600% of functional test development times. End item functional testing has shown yields from these in-circuit tests to be 93% to 100%. In-circuit board level test development costs are to three times less costly, depending on the complexity of the board. This development cost savings, coupled with cycle time reduction represents a significant average development cost savings per board. Test times have also been reduced to present additional cost savings using in-circuit testing (Table 3-1).

**TALBE 3-1. TEST TIME SAVINGS ESTIMATES**

TEST TIMES	
Part Number	Savings Test Time Per Board
A	98%
B	99%
C	99%
D	97%
E	97%
F	97%
G	97%

Also, HSEMC's method of fixture development included developing a fixture for each board being tested. This method was expensive, time consuming, and contained no self test capability. Fixture failures caused many intermittent failures that were a burden to troubleshoot, and resulted in high maintenance and repair costs. After facing constant fixturing problems and high fixture design and development costs (with end item acceptance testing), Hamilton Standard teamed with an external supplier to develop a common fixture to contain self test capabilities. Hamilton Standard and the external supplier maintained goals to decrease cycle time, increase reliability, increase redundancy (sharing), minimize change over time, minimize calibration time, incorporate self-health check, and effective use for engineering development.

Full documentation of the test fixtures were required to have good correlation between identical fixtures. Programming time reductions of 50% to 70% were projected. Initial test fixture development costs were 2% to 30% higher but drove future development costs down 52% to 70%. This cost savings coupled with automatic fixture troubleshooting (fixture self-test), reduced all-over test development and cycle times dramatically.

In-circuit production testing at HSEMC has been found to reduce both non-recurring and recurring costs, industry wide. Cycle time reductions of 80% have been accomplished by using the in-circuit test methods versus functional board testing. Functional board testing at the production level has been determined to be redundant with yields of 93% to 100% using in-circuit testing. By standardizing test fixtures, Hamilton Standard has eliminated many time-consuming failure localization problems that usually point to the fixture as noise and continuity failures inherent in many fixture designs. Fixture failures are found during self test and not after exhaustive studies of why the board is failing.

#### **FAILURE REPORTING SYSTEM**

##### **Automatic Data Collection**

The Hamilton Standard Electronic Manufacturing Center (HSEMC) has implemented an automatic data collection system that makes engineering design, test results, and failure data available for factory-wide review. This system readily provides important information to managers and design and test engineers. Failure reports and design data are current and accessible for study.

Hamilton Standard has developed a UNIX-based data collection system that is linked factory wide through Ethernet lines to PC/UNIX networks. Design engineers enter design data and specifications that can be used by the test engineers when required. This effort represents a vast

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improvement over the previous time-consuming, non-current paper trail consisting of failure report cards that were routed to personnel responsible for writing failure reports. The new method has eliminated the long lead times for failure information reporting to the appropriate level. The new system automatically generates test reports that are immediately inserted into the data collection database. At that time, they are available for review by all levels of development including management and Defense Program Representative Office (DPRO) representatives.

When test engineers are troubleshooting failed boards, they have all design data and specifications available on line and do not have to locate information manually in the design department. This method works equally well for design engineers to view data being taken on their designs. System alarms – reporting information to the foreman, lead man, operators, and inspectors for immediate action – are programmed into the database. This system generates real-time SPC charts and allows for computerized scheduling of preventive maintenance and calibration of test equipment. The system is a graphical user interface that uses a point-and-click, menu-driven operator. Overall, it allows for statistically in-control processes, management awareness of recurring problems, validation of proper corrective actions, early address of customers concerns, and no delayed shipments due to questionable test results.

### **3.3 PRODUCTION**

#### **MANUFACTURING PLAN**

##### **Continuous Flow Manufacturing**

When HSEMC introduced continuous flow manufacturing (CFM) into its production line, it eliminated many problems such as a push system versus pull system. Production bottlenecks were also hidden by the large amount of work-in-process (WIP), and inventory levels far exceeded customer demands. Substantial rework was performed; products traveled long distances in the process; many processes were non-value added, and the cycle time through the process was excessive.

The most important step in Hamilton Standard's CFM improvement process was to obtain total involvement of all associates from the director level to assembly associates. Three teams were organized with communication linkages provided by team leaders serving on the next level team. The Steering Committee was chaired by the General Manager, and the Sector Support Team Leader was a member of the Steering Committee. The Implementation Team Leader was a member of the Sector Support Team. Each team met weekly to discuss quality and product flow. They discussed production requirements and what the team needed to do to

meet them. The processes were flowcharted and non-value added functions eliminated or reduced. Setup time reductions were made to the processes.

Training in CFM techniques was provided to everyone at the Electronic Manufacturing Facility. True customer demand was identified and work was scheduled accordingly. Daily and weekly production scheduling – called TAKT Boards – were implemented in each of the work cells to provide visibility to the production requirements. The TAKT Boards showed the daily and weekly production schedule, WIP, completed product, cycle time, and easily identified bottlenecks in the process.

A Kanban system was implemented for WIP so that only the amount necessary to meet delivery schedules was allowed on the floor. With the Kanban system, problems were not masked by large quantities of WIP and the root cause of problems had to be addressed and corrected immediately. Operators were certified to inspect their own work with periodic audits by quality to ensure that quality standards were being maintained.

Point-of-use storage was implemented on the floor with a Kanban system. Only the necessary assets to support the production schedule were allowed, and components were stored in cabinets on the production floor. First-in/first-out inventory rotation was maintained using a two bin system. The active bag had components pulled from it until it was depleted. The bar code label on the bag was then scanned and a new label printed in the finished stores, triggering the issue of another bag of material to the floor. The next implemented step was the Supplier Point of Use (SPOU) where the vendor delivered parts as needed directly to the manufacturing area.

Problems are now identified as to the root cause and solved rather than "band-aided." Unnecessary processing and motion have been minimized, and the number of steps to produce an analog driver card has been reduced from 84 to 58. One product now travels 1.5 miles instead of the 12.5 miles before CFM. Manufacturing is now based on a pull system, allowing associates to concentrate on building what is needed rather than building inventory. The factory cycle time has been reduced from 8.6 months to 2.9 months and lot sizes are now one to five versus 15 to 20 before CFM. The pull time for a work order in finished stores is now 24 hours compared to two weeks under the prior system.

#### **QUALIFY MANUFACTURING PROCESS**

##### **Process Analysis for Manufacturability**

Hamilton Standard applies the Process Analysis for Manufacturability (PAFM) technique at its facility in Farmington, CT to characterize and optimize manufacturing processes. This methodology requires understanding

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the technical process, collecting and analyzing usable data, developing a new or modified process, and integrating the new manufacturing process into the design of new products. The strategy for improvements is to form small multi-disciplined teams that are focused on a particular problem or process activity. By attending a five day training course tailored to the knowledge and skill of a given group, each HSEMC team is trained in statistical techniques, team dynamics and process metrics. The PAFM methodology is used for all organized teams.

The wave solder process team provided an example of a team focused on specific issues – solderability issues. The team developed a Pareto chart on the solderability of various printed wiring board components. The chart reflected that close to 62% of solder defects were attributed to two capacitors. Further investigation uncovered that 57% of the solder problems for the two capacitors were due to dewetting. Continued root cause analysis traced the dewetting back to a specific component manufacturer of the capacitors. It was determined that some other companies were also having similar problems with these particular components. The problem was created when the component leads were bent for board insertion. The bending caused nickel to be exposed at the bends, and solder would not flow properly on nickel. The team then developed a short, intermediate, and long term plan to address the problem. \ The short term plan required removing the nickel and retinning of the leads to continue immediate production. The intermediate plan required the leads to be bent at a different height so the solder would flow on the straight part of the leads rather than at the bends. The long term plan required the supplier to remove the nickel and improve its tinning process.

Without a regularly applied, sound methodology such as PAFM, simple problems could easily develop into long term hit-and-miss ones. The solderability team has continued to improve the process and has targeted .27% or below for solder defect rate. Once it has achieved this goal, sampling techniques can be used which will further reduce product costs.

## PIECE PART CONTROL

### Source Inspection Laptop Kit

Hamilton Standard has implemented a computerized system to eliminate inspecting incoming components for items such as conformity and verification of correct engineering level. The Source Inspection Laptop Kit (SILK) provides resources to HSEMC associates to assist its suppliers in changing emphasis from traditional inspection to process controls so source quality assurance enhances the

supplier's value-added position in the procurement process. This goal is accomplished by making required, real-time information available for the supplier to produce and ship parts that meet the customer's specifications. Information such as purchase order requirements, specification and engineering change notification revision number, and product alerts is contained in the system, and Hamilton Standard source inspectors and suppliers have access to this information.

The SILK system has greatly improved the percentage of field acceptable material. In 1990, only 38% of all mechanical product receipts were field accepted. By the end of 1991, that number had risen to 63%, resulting in shorter cycle times, as well as a product that meets specification and is ready for immediate release to the production floor.

### Supplier Point-of-Use

Hamilton Standard maintains that as the electronics industry strives to become more efficient, non-value added processes must be reduced or eliminated. The traditional system of ordering all necessary components of an assembly when an order comes from a customer is extremely inefficient. HSEMC has developed a system that not only removes the inefficiency, but encourages a better relationship with suppliers.

The Supplier Point-of-Use (SPOU) is a technique that returns the responsibility for a quality product back to the supplier. Hamilton Standard enters into Long Term Agreements (LTAs) of typically three to five years with suppliers, providing them with production schedules to allow them to plan their production schedules. Also, buy issues under an LTA can be resolved up-front before the requirement for parts affects the manufacturing floor. The LTAs facilitate substantial streamlining of the procurement process to the point that when a point-of-use bin on the manufacturing floor needs to be refilled, an operator simply wands a bar code on the bin to initiate the purchase order. When the purchase order is initiated, the supplier will typically refill the bin within nine calendar days. SPOU provides exact, up-to-date order information to the supplier that allows parts to bypass receiving inspection and finished stores upon receipt. To further enhance this system, Hamilton Standard has implemented the use of electronic data interchange to communicate with suppliers.

Since the advent of SPOU, HSEMC has seen average lead times reduced from 47 weeks to 31 weeks, with an ultimate goal of eight weeks. Approximately 60% of all part numbers will be on LTA by the end of 1993. The use of SPOU has also resulted in a major reduction in inventory since

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components are delivered directly to the manufacturing floor immediately when they are needed.

## SUBCONTRACTOR CONTROL

### Certified Supplier Program

The Hamilton Standard Manufacturing Center implemented its Supplier Certification Program in April of 1993 with objectives to identify suppliers with excellent performance and process controls and assist suppliers in getting their processes under control through training and process reviews. The end result was anticipated to be that Hamilton Standard could eliminate the incoming inspection process for the part numbers that were certified. As of October 1993, 50 assessments of suppliers have been performed and 11 suppliers have been certified.

A certified supplier must review and accept the Hamilton Standard Quality System. The key characteristics of the product must be identified, monitored, and controlled using SPC methods, and the vendor must be committed to Total Quality Management. Action plans are required to be developed for historical concerns, and the supplier's process capability must be demonstrated at an on-site review. A supplier must establish a Long Term Agreement with Hamilton Standard with an implementation plan in place for Electronic Data Interchange (EDI). A Supplier Point of Use plan must also be developed. The certification can be for an individual part number, a family/commodity of parts, or at the facility level for all parts.

The implementation review covers work instructions, configuration control, manufacturing procedures, producibility, critical processes, SPC, manufacturing tools, special test equipment status and control, material handling methods and procedures, discrepant material processing methods, HSM 9 introduction and review, Source Inspection Laptop Kit introduction and review, purchase order administration and documentation review, EDI, business performance review, Long Term Agreement, certification(s) applicability, training methods and effectiveness, safety, and EPA initiatives. Any action items are documented and responses are required. Action items are also given to Hamilton Standard to correct discrepancies or ambiguities.

The certified supplier benefits from the process by the establishment of the Long Term Agreements. The product is released without customer intervention, increased business opportunities exist, and the product yield is enhanced through adoption of the Hamilton Standard Advanced Quality System. Hamilton Standard benefits from reduced procurement cycle times, enhanced product availability, more expedient and effective corrective actions, and superior product quality.

## ENVIRONMENTAL ISSUES

### Environmental Program

The Hamilton Standard Electronic Manufacturing Center has developed an environmental program that will help it remain competitive in an increasing environmentally conscious marketplace. This program is designed to keep HSEMC ahead of quickly changing regulations and to promote the proper use and reduction of hazardous materials for the benefit of the community.

The Farmington facility has its own environmental department (that is supported by a central department at the Windsor Locks facility) to address the environmental needs of the site. The department, consisting of four associates, is responsible for reviewing and approving environmental plans, policies, and programs for the facility, and it must approve the necessary human and financial resources to administer these programs. The department provides direction to the environmental teams and creates and sustains interest and communication in environmental awareness throughout the building. The department must also check the progress and ensure the appropriate procedures and activities are in place to achieve and maintain compliance with current environmental regulations.

The department associates also provide guidance to the Environmental, Health, and Safety Team which consists of up to twelve members who are representative of the facility's population. There are also sub-teams that handle special tasks within the facility. These teams help to make associates conscious of environmental concerns.

The environmental department has established certain goals that extend beyond the necessary levels to achieve environmental compliance. For example, it is taking steps to reduce and prevent pollution including elimination, substitution, or optimization of hazardous materials. It is also a voluntary member of the Environmental Protection Agency (EPA)'s program to reduce 17 hazardous chemicals by 33% from 1988 levels by 1992 and by 50% by 1995. The department is attempting to eliminate all ozone-depleting substances from the facility but has been hindered by old specifications which require the use of Freon. Freon usage has dropped from 116,000 pounds in 1990 to 50,900 in 1992 at HSEMC, and remains low in 1993, particularly after the installation of an alcohol-based, semi-aqueous cleaner.

HSEMC's team approach has made environmental compliance every associate's responsibility. Associates are able to suggest design changes that eliminate or reduce hazardous materials, and the designers are able to use manufacturing inputs early in the design process.

Hamilton Standard has carefully considered the increasing need for environmentally conscious manufacturing. It has developed a program that reaches from upper management

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to every associate. This program considers the future and what is best for the company and the community.

### **3.4 LOGISTICS**

#### **TRAINING EQUIPMENT AND MATERIALS**

##### **Inventory and Asset Management**

Hamilton Standard EMC has pursued an aggressive inventory reduction program since 1991. Inventory and asset management has become the job of every HSEMC associate. In many companies, the administration of inventory and assets is the responsibility of management, often with an incomplete view of where improvements can be made. Many times, the associate on the manufacturing floor can best see where improvements would be effective. Often these improvements involve the reduction of inventory and other assets to free capital for expenditures on such items as research and development, employee training, and new equipment.

This inventory and asset management program was a conscious step in Hamilton Standard's pursuit of excellence. The program began with training for all associates to increase awareness of asset and inventory management. Training included topics such as what inventory is, associated costs of excess inventory, what the company is doing about it, and what the associates can do to help. These topics were presented in terms that were understandable to associates at every level, and comparisons were made to managing assets – such as homes or cars – in an individual's life. Benefits of reduced inventory were explained, as well as the advantages of increased capital. Training also explained ways to manufacture economically. Training provided all associates the skills and knowledge to be inventory and asset managers.

One way associates were able to reduce inventory was to reduce cycle times, thereby reducing the amount of time inventory in the facility. Ideas for reducing inventory and managing other assets were presented to management through gainsharing program meetings and team meetings. Rewards were presented to individuals and teams for meeting goals and for contributing good ideas. These rewards ranged from pizza lunches and getaway weekends for the teams to yearly bonuses of six percent last year. These rewards help to ensure that the flow of good ideas would be continuous.

Hamilton Standard has successfully implemented an inventory and asset management program. A primary reason for the program's success was the empowerment and training of associates to do the job. Associates have taken personal responsibility for change and were aware of how that change could affect the business. This increased aware-

ness helped guarantee continuous improvement in terms of inventory reduction and asset management from good ideas at all levels.

##### **Process Control Strategy**

A unique video delivery training method has been implemented at HSEMC to teach process control. This method allows training to be conducted in a timely and cost effective manner, and is flexible as to the type and amount of training for each associate.

Hamilton Standard has developed a process control strategy that is based on training associates to enable them to implement better process control. This training consists of three parts – CFM, which consists of cycle time reduction and reduction in lead time and rework; SPC applied to key processes; and process management training that contain several unique and beneficial factors.

Training is conducted using a just-in-time application of video modules. Because training often precedes implementation, many important points are forgotten. Video module training allows the material to be viewed just prior to implementation. Also, the videos can be used as a refresher course to help solidify key points after they have been applied. These videos are specific to the Farmington facility's products and processes, manufactured by local associates. Workbooks that accompany the videos give associates a hard copy of the presentation to which they can refer in the future.

A valuable tool in the video delivery training method is the resource list – a list of associates trained in certain areas who can give other associates help if needed. These videos are arranged in modules to allow an associate to view only those videos required to instruct in the necessary skills. The videos can be viewed individually or by a group, thereby providing flexibility in the training schedule with no obligation for the trainer to handle multiple sessions. Hamilton Standard's program of process control implementation has been successful partly because of the video presentation modules and the resource list – important tools in teaching SPC and process management.

### **3.5 MANAGEMENT**

#### **MANUFACTURING STRATEGY**

##### **Manufacturing Strategy Process**

In the 1980s, Hamilton Standard Electronic Manufacturing Center viewed itself as an inwardly focused company with a short range outlook. Its strategic planning relied on capital as the primary means and emphasized pushing product out the door. Manufacturing strategy was isolated

from the business strategy of bid to win on any program that came along. This approach resulted in several years of subpar performance characterized by large operating losses, low quality, and dissatisfied customers.

HSEMC's new manufacturing strategy was developed after benchmarking numerous strategic planning processes. It was also based on a National Center for Manufacturing Sciences global benchmarking study that documented best demonstrated practices in strategic planning processes. The HSEMC manufacturing strategy incorporates elements of Agile Manufacturing and the Air Force's Lean Manufacturing initiative.

Manufacturing strategy was linked to the business unit strategy. Customer needs, the divisional vision, competitive environment, and environmental issues were addressed and translated into action plans that were aligned with the company's strategic goals. Benchmarking was used to identify best business practices and metrics that together with the Malcolm Baldrige Criteria are used to measure manufacturing performance against the best in class and set goals. A three to five year plan was developed and framed in terms of a portfolio of actions to coordinate, integrate, and facilitate implementation. The portfolio was flowed down through the organization and serves as a plan of action for continuous improvement teams.

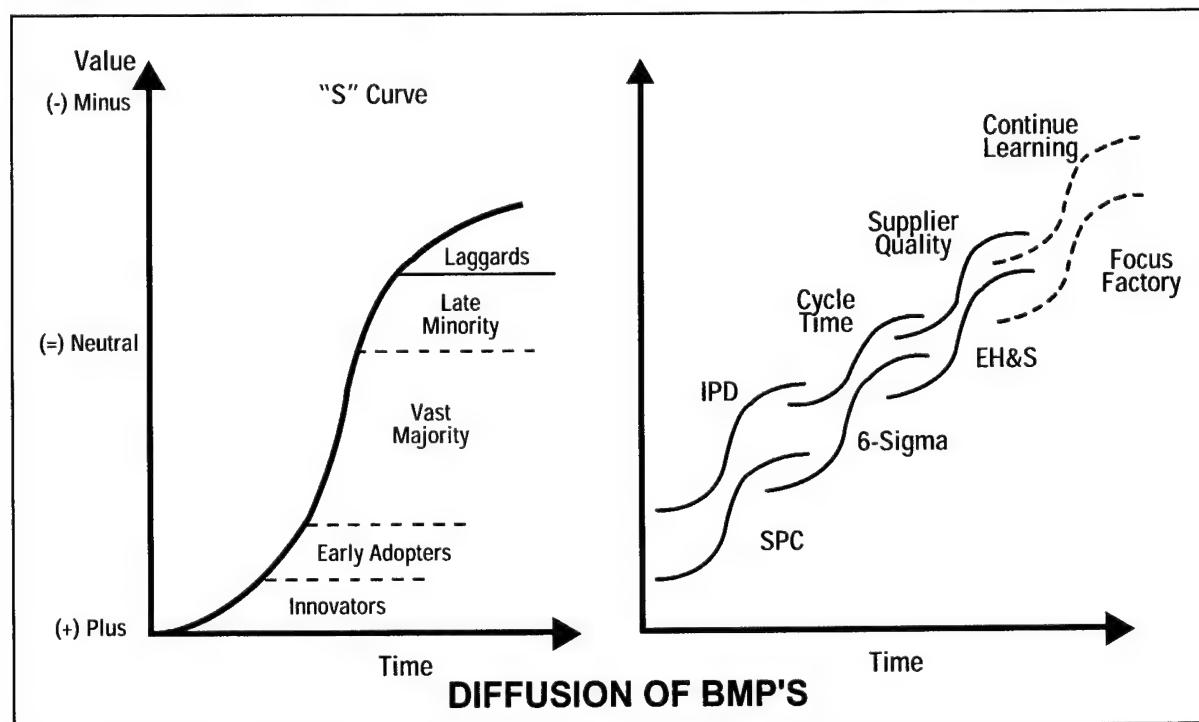
A key element of the manufacturing strategy was the timing and speed of implementing best business and manu-

facturing practices. Figure 3-2 illustrates an "S" shaped curve that represents the value over time of adopting best practices. In order to maintain a competitive advantage, HSEMC strives to identify best practices and be one of the "early adopters." The figure also illustrates that the environment is changing and processes and practices are developing so rapidly that a company must be an early adopter on a continual series of "S" curves to stay competitive.

The new manufacturing strategy has helped transform HSEMC of the 1990s into a outward focused, long range thinking company that anticipates changes in processes and technology. The process emphasizes human resources and new process development over capital. Communication and linkage are also key elements. This strategy has helped to make the company profitable over the past several years and has contributed to improving first time yields by 70%, reducing scrap and rework by 30%, decreasing cycle times 70%, reducing hazardous waste by 50%, improving against the Baldrige criteria by 249%, and improving on-time deliveries by 46%.

## Customer Satisfaction

The Hamilton Standard Electronic Manufacturing Center employs a well-developed and implemented process for satisfying customer expectations and requirements. Its goal is to consistently meet or exceed customer – both internal



**FIGURE 3-2. MANUFACTURING STRATEGY TIMING/SPEED**

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and external – expectations and requirements. The method is a simple, five step process based on the Deming PLAN, DO, CHECK, ACT cycle.

STEP 1	Identify who the customer is.
STEP 2	Determine what the customer wants.
STEP 3	Satisfy the customer.
STEP 4	Determine whether the customer's expectations and requirements were met.
STEP 5	Identify ways to do it better the next time – improve the process.

Associates and DPRO personnel receive formal training and practice in this process. The process has become integral to all team activities and is an important factor in associate performance evaluations. The process provides Hamilton Standard associates the tools and knowledge to determine customer requirements (even when the customer is unsure) and measure how well the requirements were met.

Benefits have included improved communications within the plant and a vastly improved working relationship with DPRO – now a true partnership. It has improved relationships with external customers and helped eliminate the need for customer representatives on site.

### **External Involvement for Manufacturing Research and Development**

HSEMC has found that there are many benefits, when solving industry-prevalent problems, to collaborating with other industrial and government partners on research and development (R&D) efforts. These collaborative efforts serve to minimize the risk of the singular company investment while leveraging the strengths within the electronics manufacturing industry.

In the 1980s, HSEMC funded R&D efforts internally, isolating its ideas, experiences and findings. Forces of change in the late 1980s such as new electronic packaging technologies increased competitiveness and a heightened awareness of environmentally conscious manufacturing, brought soaring development costs and long lead times. While having the need, Hamilton Standard lacked the resources such as adequate funding and experience in certain critical technologies to develop the new technologies needed to remain competitive. HSEMC decided to openly communicate with other external entities thereby leveraging its internal resources for future development efforts. This strategy has enabled HSEMC to enhance its existing manufacturing process capabilities beyond what it

could have with its limited internally available resources.

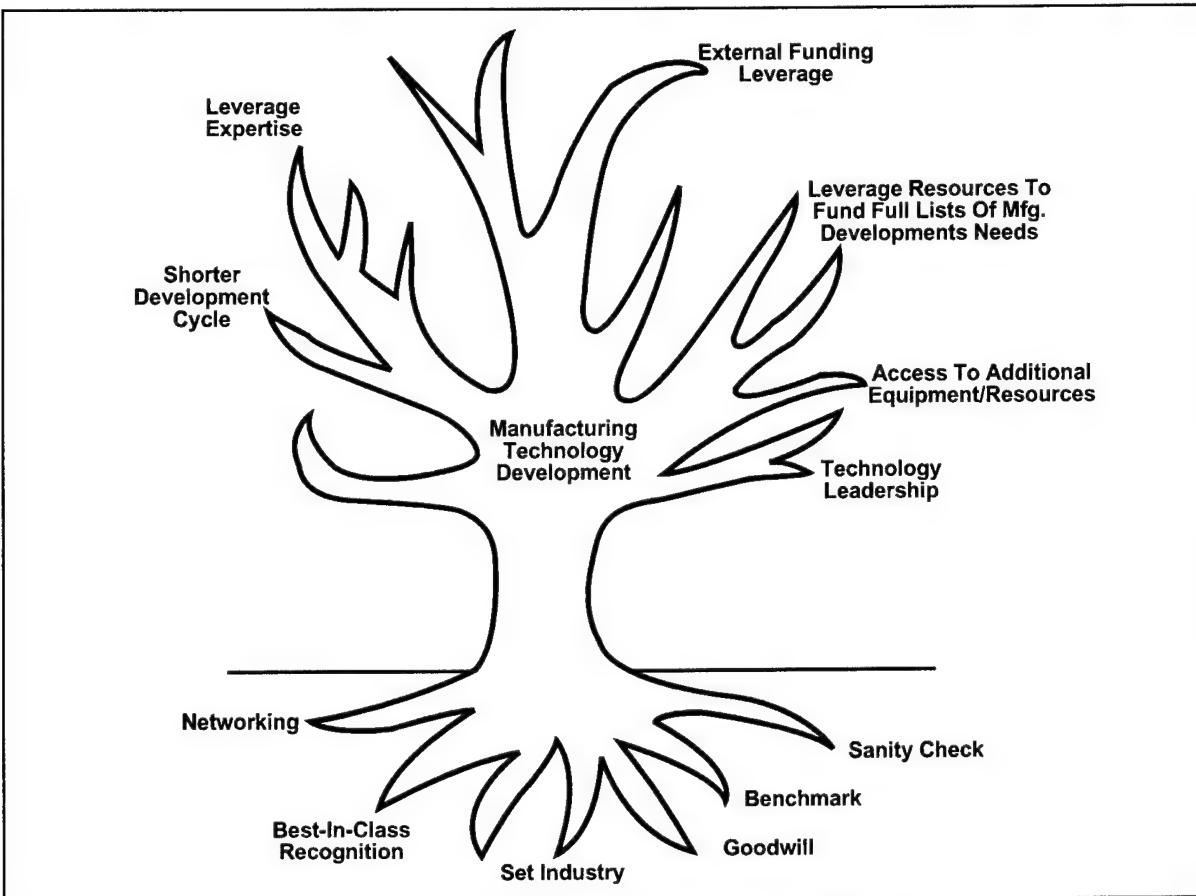
HSEMC now teams with the national Center for Manufacturing Sciences, Department of Commerce, Advanced Research Project Agency, Department of Defense, internal United Technologies division, and other consortia. It has developed a discrete process plan flow chart delineating the steps involved to implement a technology insertion plan. Today there are 11 external projects with benefits such as those illustrated in Figure 3-3.

Two examples of these successful external projects include the Chlorofluorocarbon (CFC) Elimination Program and the Lead Free Solder Project. In 1989, HSEMC emitted 325,000 pounds of CFCs. Through its collaboration with industry partners, HSEMC now plans to have completed the elimination of CFCs from its manufacturing processes by the end of 1994, two years ahead of the required legislation. The Lead Free Solder Project is proactively evaluating environmentally safe alternatives to lead-based solder alloys used in electrical/electronic interconnections. This 30-month program is based on developing a comprehensive matrix of solderability and properties, assessing these properties and evaluating their ability to be used in today's manufacturing environment. The findings are scheduled to be complete in the second quarter of 1995.

### **Benchmarking Process**

Benchmarking other best industry practices is considered by the Hamilton Standard Electronic Manufacturing Center to provide the basis for its journey in continuous improvement. A pilot benchmarking database on over 40 visits to other sites has been established to facilitate the coordination and deployment of benchmarking information within the facility.

When HSEMC undertook its initial benchmarking efforts, it found that there were redundant and unfocused efforts such as trip findings not readily available. Improvement in company benchmarking was needed to realize the full return on investment for existing efforts and to coordinate internal efforts to ensure conformance with the ethics of benchmarking. HSEMC benchmarked two Malcolm Baldrige award winners and one large commercial electronics manufacturer to assess common best practices. Using Xerox's Seven Steps Toward Benchmarking Maturity, it achieved the fifth level of establishing an organization-wide data base containing summaries from over 40 trips. To communicate this information, a Benchmarking Coordination Team was established to prepare those who will travel to coordinate and focus multiple efforts, submit newsletter articles, train database users, and serve as the benchmarking champion to a business unit. Access to the database was reached through a VAX terminal, UNIX workstation, or a PC. Benchmark confidentiality is maintained.



**FIGURE 3-3. EXTERNAL INVOLVEMENT**

HSEMC has learned that a dedicated focal point is needed; that the database must be easy to use and maintain; and that benchmarking personnel are to provide a service, not act as auditors. The benefits include eliminating redundant efforts, providing a quick review of previous efforts, and providing secondary assistance in-house from the associates who conducted the benchmarking effort.

### Finance Office Kaizen

At Hamilton Standard, continuous improvement has been integrated not only on the factory floor, but also in the office area. The finance section used the Kaizen method to revamp its office area in two phases. The first phase was initiated in July 1993 and the second followed in September 1993. This modernization process included the collective efforts and ideas of each associate in the work unit. Results of the changes included a cycle time decrease of 83%; a walking distance decrease of 98%; elimination of 12 tons of paper; and improved ergonomics. Benefits derived include en-

hanced visual control, improved communication, streamlined process flow, and the obvious sense of increased self-esteem and teamwork among associates.

### Continuous Improvement

The need for a fundamental change in 1987 at Hamilton Standard Electronic Manufacturing Center in how business was conducted – and ultimately the survival of the unit as a corporate entity – prompted it to embark on a new management philosophy. HSEMC has maintained a vision to be a global leader in providing high quality aerospace systems, components and services. It was – and remains – committed to a process of continuous improvement to meet customer expectations, to create associate opportunities, and to achieve superior business results.

The change implemented at HSEMC included changing from management control to leadership, from individual performance to team effort, from fire-fighting to forward thinking, from correction to prevention, and from check to

trust. The company invested time and money in focusing the collective efforts of both management and the work force into a single direction, a direction in which each associate understood his/her part of the process.

The Continuous Improvement Cost Competitiveness Process (CICCP) has become Hamilton Standard EMC's accepted mode of conducting business. CICCP focuses on processes not problems and includes all the collective resources of each department. Its requirements include clearly identified measures of performance, performance targets for the year, and benchmarking of goals.

This commitment to readily known processes such as Hoshin planning, Kanban, arachnid charts, teaming, and best-in-class benchmarking has become the foundation of a business philosophy focused on satisfying the needs of value-conscious customers into the coming century. In 1991, HSEMC equaled or exceeded 4 of 6 corporate goals resulting in an associate gain-sharing bonus of approximately 4% per associate. In 1992, it equaled or exceeded 5 of 6 goals with a payout of 5% per associate. In 1993, a payout of 5% to 7% is expected. Hamilton Standard was selected as the sole winner of the 1993 Connecticut Quality Improvement Award that uses the same criteria as the Malcolm Baldrige National Quality Award. This award is in recognition of the five years of systematic approach to continuous improvement and cultural change.

## PERSONNEL REQUIREMENTS

### Work Environment

In the 1990s, the Hamilton Standard Electronic Manufacturing Center (HSEMC) focuses on people, values, and their continued development as the most important force in the company. Key factors for the HSEMC in developing an environment for associates to develop their capabilities include knowing that 75% of the work force needed in the year 2000 is already in place, leveraging unique human capabilities, changing the role of the associate, and parlaying all of these things to reduce cost and price to the customer.

HSEMC's drive to enhance the culture and value system encompasses 10 major focal points (Figure 3-4). These principles include customer satisfaction (everyone is a shareholder); environmental (more can always be done); training to continually upgrade associate skills; diversity (every person is valued); career development to provide incentive, assistance, and support to facilitate individual development; ethics (winning with integrity intact); health and safety (the well being of the associates enhance the well-being of the business); open and participative communication; empowerment (responsibility and authority to determine how a task is to be done is delegated to the associates performing the task);

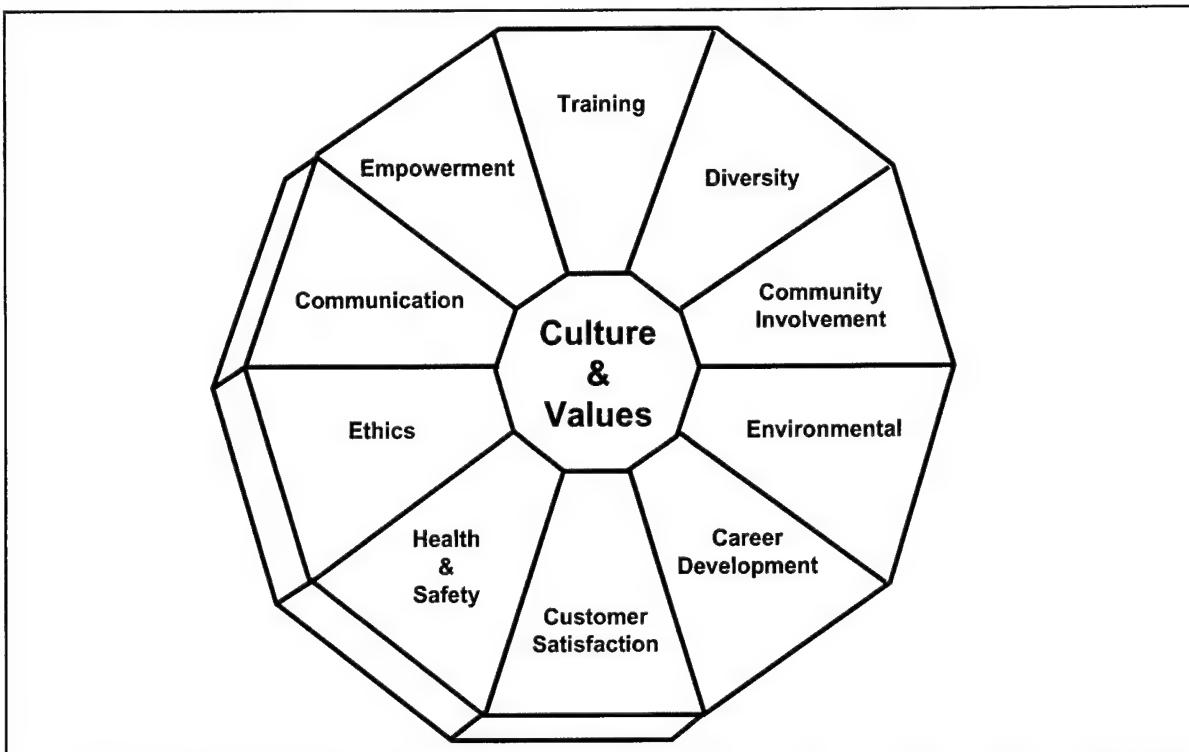


FIGURE 3-4. WORK ENVIRONMENT

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and community involvement (each associate is a viable, contributing member of society).

This is a system of processes. Hamilton Standard realizes that communicating change is difficult – implementing change is more difficult – and that all walls must come down. Supportive management and ethics application are also critical factors. They cultivate change agents, and assume a solid and fundamental consistency of purpose. The company understands that to survive in the value-driven market of the 1990s, change is essential.

### All Salary Workforce

Until recently, the Hamilton Standard Electronic Manufacturing Center had a two-tiered compensation system of hourly and salaried associates similar to that found in other manufacturing sites. HSEMC decided to eliminate this traditional system and implement a single compensation system for all employees. This change was motivated by a need to unify the workforce, break down invisible barriers to communication, simplify systems, reduce administration costs, and enhance organizational agility.

Effective January 1, 1993, HSEMC transitioned to an all salary workforce following a July 1992 announcement by the Business Unit Director. Progress updates were given in periodic meetings through the remainder of 1992. Human Resources held small group meetings with all hourly associates to explain transition improvements. A Financial Services Seminar was conducted to assist associates with budgeting and other concerns.

Under the salary system, associates receive greater vacation and sick leave eligibility, enhanced short and long term disability benefits, and more excused absences with pay than under the hourly system. Other changes included discontinuing cost of living allowances, vacation incentive accrual, and automatic increases. Payroll checks are now issued semi-monthly rather than weekly.

Benefits to the process have included an overall simplification of administering and using the system. Invisible barriers to communication have been eliminated resulting in a more unified and focused workforce. Costs have essentially remained unchanged; however, there was an unexpected decrease in the cost of sick pay which had been expected to increase. The response to going with an all salary workforce at HSEMC has been that this is a win-win situation for everyone. The next steps in implementing the transition involve redefining job descriptions and re-engineering the compensation/merit system.

### Communication Process

Associates at HSEMC understand that to enhance the atmosphere of the work place, individuals need to improve

communication skills. To accomplish this goal, Hamilton Standard has developed a communication process to facilitate consistency of understanding. This process model has defined key elements such as enduring consistency through understanding of the message; reviewing the model and principles; determining applicable needs and responsibilities; applying the model to the message to be communicated; communicating; soliciting feedback, and improving skills. Individual responsibilities are also a part of this model. (Table 3-2).

Associate training in the use of this process is an ongoing effort to bridge communication gaps with the customer, through goal setting and interpersonal exchanges. Information is taught to be conveyed consistently, clearly, interactively, and rapidly. To verify that the message has been clearly sent, verification, clarification, re-statement, paraphrasing, and summarization skills are used. Requirements and responsibilities of all parties are also clearly delineated and understood.

**TABLE 3-2. HAMILTON STANDARD PRINCIPLES OF COMMUNICATION EXCELLENCE**

- Be committed to becoming an excellent communicator through the process of continuous improvement.
- Know my communication strengths and weaknesses.
- Ensure information is communicated consistently and in a timely manner.
- Maintain ethical standards and respect confidentiality.
- Set the example for communications within my team and take responsibility for my team's overall communication effectiveness.
- Practice open, two-way communications.
- Tailor my communications to the needs, values and beliefs of my audience.
- Respect the time of others – get to the point and communicate only essential information.
- Ensure my actions are consistent with my words to enhance my credibility and establish trust.
- Practice active listening to increase my ability to understand others.
- Solicit feedback on how I communicate, to measure if my message is getting across.

**KNOW MY COMMUNICATION NEEDS & RESPONSIBILITIES**

Hamilton Standard has already realized many benefits of an open and interactive communication process including saving valuable personnel time; decreasing rumors; improving productivity; teaming; reducing confusion and mistakes; and presenting a consistent message to all employees. In all top-down communication, associates want to hear the truth, and Hamilton Standard believes this is a long-term effort, requiring associates to take personal responsibility for this communication process to be fully effective.

## DATA REQUIREMENTS

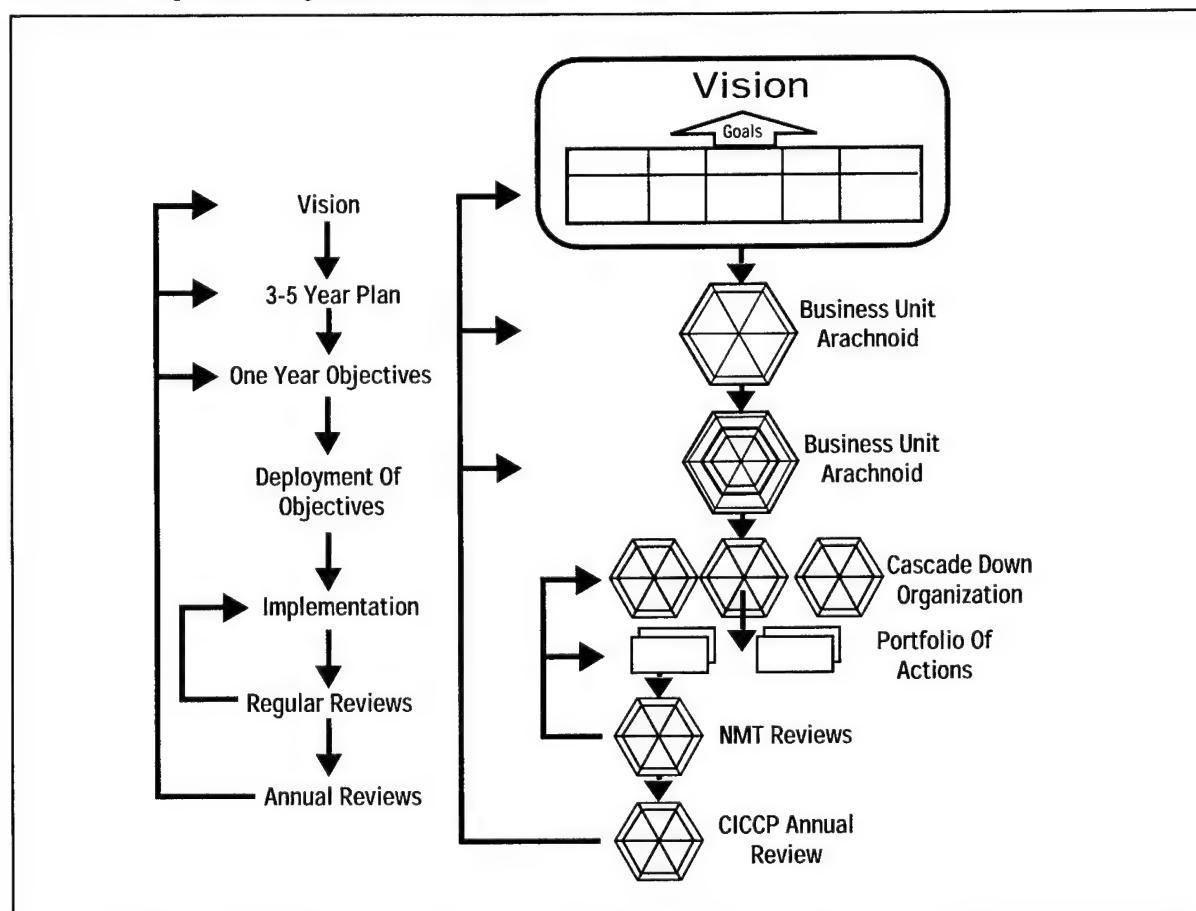
### Metric Alignment/Flowdown

Each Hamilton Standard business unit, including the Farmington, CT Electronic Manufacturing Center, develops annual objectives and implementation plans that focus on achieving divisional level objectives and satisfying individual customer needs. The HSEMC revamped its management approach by thinking long-term versus short-term, multiple lines of organizational communication

versus isolation, and a visionary process of focus and multi-functional alignment.

Key elements of the Hoshin planning process were deployed at HSEMC to facilitate alignment of the division level vision with functional unit metrics. Division level direction was summarized in the company vision card which establishes a long term and 3 to 5 year objective (Figure 3-5). The vision is systematically broken down into a 3-5 year plan, one year objectives, objective deployment, implementation, and regular and annual reviews feeding back to the initial plan.

A key visual aid used by Hamilton Standard is the arachnid chart (Figure 3-6). At a glance, it quantifies the unit's goals and the cascading of these goals down the organization. Arachnid metrics are reviewed to ensure business segment plans are aligned with the divisional goals and available resources. Results have contributed to a first time yield increase of 70%; scrap/rework down by 30%; cycle time down by 70%; use of volatile organic compounds down by 85%; and on-time delivery up by 46%.



**FIGURE 3-5 METRIC ALIGNMENT/FLOWDOWN – HOSHIN PLANNING PROCESS**

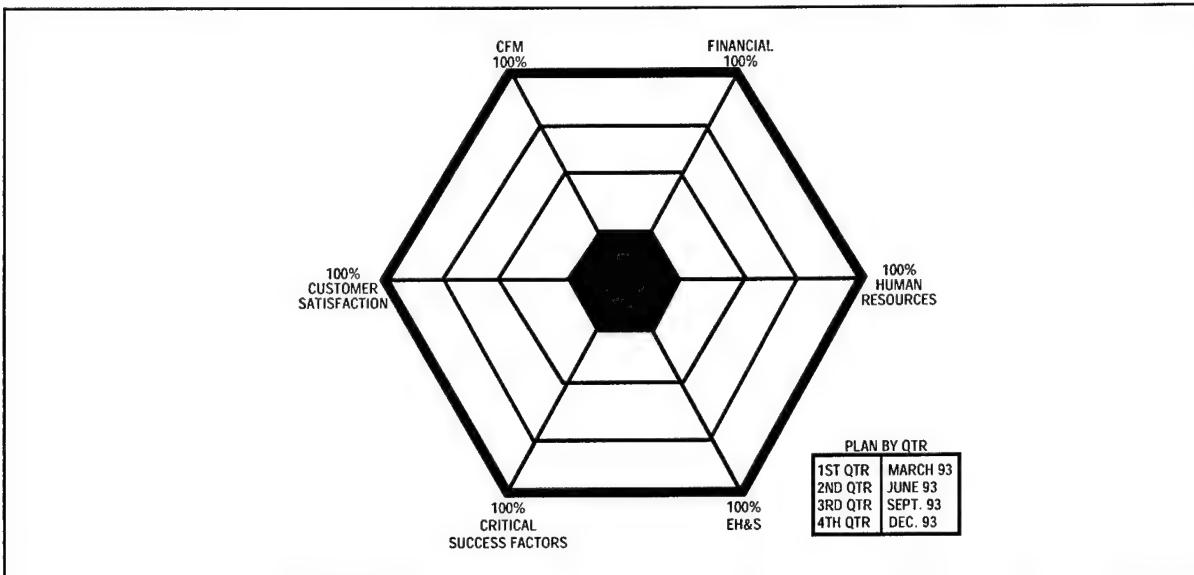
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HSEMC has determined that the following are critical elements in the metric alignment/flowdown philosophy:

- Keep the data visual
- Keep it simple
- Learn to listen

- Delegating authority and empowerment
- Communication, communication, communication.

Measured value metrics include presenteeism (not absenteeism), associate recognition, associate development, community involvement, on-time delivery, quality, lead time, cycle time, safety, scrap and more.



**FIGURE 3-6 CONTINUOUS IMPROVEMENT KEY PERFORMANCE METRICS**

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# **SECTION 4**

## **INFORMATION**

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### **4.1 DESIGN**

#### **DESIGN POLICY**

##### **Design for Environment**

To comply with the environmental requirements imposed by federal, state, and local governments, the Hamilton Standard Electronic Manufacturing Center (HSEMC) has instituted a policy for hazardous materials reduction to meet or exceed regulations or suggested federal EPA goals. To implement this policy, Hamilton Standard developed Technical Standards and Work Instructions to provide technical data and recommendations to reduce hazardous materials in present and future designs.

An IPD team works with Central Environmental Health and Safety (EH&S) to assess the manufacturing environmental requirements and costs. Manufacturing Engineering and the Central EH&S approve and provide operation sheets that consider environmental and cost factors in all in-process operations. In addition, Hamilton Standard has established a Green Team to implement a process in electronics engineering designed to incorporate environmentally compliant materials in electronic products.

Hamilton Standard instituted modifications such as changing aircraft propeller counterweight material from lead to tungsten; using high density connector with compliant pin solder bus connections in selected applications; and changing primers for loctite, paints, and epoxies. The implementation of these changes resulted in the elimination of ozone depleting substances and chrome/chromate processes where possible. Hamilton Standard has eliminated CFC emissions in cleaning electronic printed circuit board assemblies by using a semi-aqueous cleaning system.

### **4.2 PRODUCTION**

#### **SUBCONTRACTOR CONTROL**

##### **Laser Marking System**

Hamilton Standard Electronic Manufacturing Center's previous method of creating nameplates was a manual, expensive, unreliable, and time-consuming process. Therefore, a cross-functional team selected by HS selected a laser marking system to replace the old system. After the equip-

ment was purchased, the team worked to develop the process in which the machine would be used. Currently, the team is working to change documentation including specifications, blue prints, and manufacturing instructions. When these steps are completed, the machine can be implemented into production.

The laser machine takes data from a central database and creates a nameplate from a variety of materials that can then be easily attached to the product. It can mark on steel by either a surface anneal marking or a laser etch. It can also mark on aluminum by paint or anodizing removal. However, the most common method of creating nameplates is the use of a two layer acrylic. Two layers of acrylate film of different colors are bonded together and the laser uses ablation to remove the top coating to reveal the color underneath. The labels have an adhesive back and are resistant to solvents, abrasion, and tampering. The material from which these labels are constructed is available in sheets, rolls, and ready cut forms. The labels can also be cut to any desired size by increasing the laser power.

The laser can also create bar coding not possible with the previous system. The marking system has also found use in a variety of other areas. Small, legible labels can be custom made to identify components or boards replacing inks or dyes which can be difficult to read.

Hamilton Standard implemented a new tool that will help to reduce costs. This system has helped reduce the standard hours to produce a nameplate by 51%. HS has reduced the cycle time by 70% and has reduced material costs by 90%. The new system is fast, flexible, modern, reliable, and capable of marking bar codes. Most important, the new system is cost-effective, which allows HSEMC to reduce product cycle-times and costs.

#### **MANUFACTURING SCREENING**

##### **Environmental Stress Screening Testing**

Hamilton Standard has addressed reducing unneeded processes in the environmental stress screening (ESS) structure to gain cost savings and optimize unit field life. The specific objectives are focusing on restructuring ESS to gain enhanced benefits from the process. Presently, 50% of the factory's energy costs result from ESS testing. Each product has an application-specific stand/interface – there is no self test available for test stands. Automated data

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collection is not available on all stands and is impossible to implement on some. This results in a recurring problem of unconfirmed failures.

Hamilton Standard plans to use ESS testing for identifying assembly defects, infant component mortality, and exposed weak areas that would reduce the mean time between failures. Improving customer satisfaction is an objective that will be met by optimizing unit field life, cost benefits, and hardware quality/reliability improvement. The cost benefits can be achieved by reducing ESS costs by a 50% minimum, reducing ESS non-recurring costs 50% minimum, reducing ESS design cycle time 50% minimum, and reducing ESS recurring cycle time 50% minimum.

These goals can only be met if ESS requirements are tailored. Hamilton Standard indicated that only two axes of vibration were required to maintain maximum benefits since random vibration along the board edge was an ineffective test along with sine wave vibration. This test deletion would result in a significant savings in concurrent vibration capability and a 33% random vibration cycle time savings. Screens should be product specific in order to optimize thermal cycle profiles. Dwell elimination and bringing the unit under test to thermal stability would reduce energy usage.

Relevant data indicated no failures occurred during the test described above. During thermal cycling, all failures occurred during ramp, not dwell. Analytical investigation verified this to be a design test. Energy reduction using the new profiles proved to be 65%, with 66% cycle time reduction.

The test strategy used to reduce costs will combine similar products with similar profiles in order to reduce the number of ovens and save floor space. Eliminating unconfirmed failures will be accomplished by improving test interfaces to contain self test and to make test stands transparent to power line transients. The HSEMC proposed changes to the current ESS structure will reduce energy consumption, reduce test stand design cycle time, reduce ESS cycle time, increase the test capacity, save floor space, and result in resource savings.

### **4.3 FACILITIES**

#### **FACTORY IMPROVEMENTS**

##### **Factory Improvements**

Until the late 1980s, HSEMC used an MRP-based manufacturing strategy. However, in an effort to reduce cycle time and improve responsiveness to its customers, HS initiated a strategy to improve its factory that is still in place.

At the heart of this strategy is a continuous flow manufacturing technique and a multi-faceted approach that has changed HS – entire organization.

To improve its overall manufacturing process, Hamilton Standard made various changes to the Farmington, CT factory. Teams were formed consisting of assemblers, technicians, production control planners, engineers, and supervisors. These teams reviewed virtually every process to determine what measures could be taken to decrease cycle time and improve test yields, while eliminating non-value added operations. Teams were responsible for other metrics such as reduction in rework and repair, conformance to schedule, and linearity of production. In addition, associates were cross trained for department flexibility, and an operator certification program was developed to help reduce separate inspection processes.

Equipment improvements were also made in areas with major impact. Surface mount assembly was accomplished faster with fewer errors by the addition of an automated pick and place system that measured the value of passive components prior to placement. A new dual wave soldering system reduced solder defects in through-hole assemblies. The introduction of water soluble cleaning technologies reduced hazardous waste, eliminated the use of ozone depleting chemicals, improved cleanliness on assemblies, improved cycle times and reduced conformal coat defects.

By refinement in communication and changes in the floor layout, improvements have been realized in virtually every area of concentration at the HSEMC. For example, in the surface mount area, cycle time was reduced from 19.1 days in 1991 to 3.8 days in December 1992. Nineteen inspections were eliminated from the process flow of one product. Another product benefitted by elimination of two inspection steps and the reduction of cycle time by 50% and the reduction of rework by 50%. Other products have had similar success.

### **4.4 LOGISTICS**

#### **MANPOWER AND PERSONNEL**

##### **Health and Safety**

HSEMC uses many techniques to maintain a successful health and safety program. These efforts have favorable results in reducing lost time and injuries.

HSEMC's safety and health program includes a formalized Pass to Medical which helps ensure that associates who are injured on the job receive prompt, early treatment. Supporting this endeavor is a part-time nurse and

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the security staff, all trained as emergency medical technicians. The active accident prevention program includes an accident investigation team that looks into the root cause of any accident, posts OSHA status charts, and department "days since last lost time accident" posters. Communication methods include weekly bulletins, area safety representatives, "concern" forms, announcements on the facility radio station, and regular articles in the newsletter. The facility also has a regular health and wellness program consisting of activities such as cholesterol screening, nutritional programs, and aerobics. Associates are also trained in ergonomics to help identify and correct problems.

This active program has resulted in substantial reductions in lost time accidents. The OSHA recordable rate has been reduced by over 40% from 1992 to 1993. The OSHA incident rate has been similarly reduced by 25% over the same period, while the OSHA severity rate has been reduced by 75%.

## **4.5 MANAGEMENT**

### **PERSONNEL REQUIREMENTS**

#### **Training**

The Hamilton Standard Electronic Manufacturing Center's ability to achieve future goals and visions depends on the ability of the associates to expand their knowledge and skill base. The company's philosophy of continuous improvement is strongly supported by a comprehensive, broad-based training program.

From 1989 to the present, the number of available courses has increased from 52 to 114, with more courses scheduled to be added. The number of hours of training per associate has tripled. A synopsis of categories and specific courses include:

#### **Qualification Training**

- Assembly and soldering
- Rework and repair
- Wire wrap
- Crimping

#### **Certification/Recertification**

- NASA (NHB 5300.4)
- Weapons Specification (WS6536)
- MIL-STD-2000A
- Forklift and operator certifications

#### **Environmental, Health & Safety**

- RCRA/hazardous waste
- Accident prevention
- CFC reduction – environmental awareness
- Ergonomics
- Hearing protection

#### **Manufacturing Process Improvement**

- Statistical process control
- Continuous flow manufacturing
- Kaizen
- Continuous improvement

#### **Associate Development Training**

- Diversity
- Sexual harassment awareness
- Reading comprehension
- High school equivalency (GED)
- Satellite college courses
- Computer training

Supporting the training listed above is a training records database of formal and skills enhancement training, on-site and off-site classrooms, and state-of-the-art visual and audio equipment.

#### **Recognition and Involvement Programs**

The Hamilton Standard Electronic Manufacturing Center has a number of programs for recognizing individual and team performance. Individual awards include Presidential Awards, Achievement Awards, Outstanding Effort Awards, Merit Awards, and Patent Awards. These are all cash awards that are either a percentage of salary or a set dollar amount. There are also team awards that include company sponsorship of team celebration events and shared cash awards.

The company also has several programs that provide an opportunity for associates to get involved and represent the company in the local community. These activities include partnerships and mentoring activities with local schools and businesses, participation in community activities, and internal fund raisers to support local charities.

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## **DATA REQUIREMENTS**

### **Labor Reporting**

Labor reporting supports the requirements of MIL-STD-1567; however, the labor reporting structure at Hamilton Standard has become a labor-intensive, non-value added task targeted for elimination at four Hamilton Standard sites. One specific building will become the pilot site to test the idea that efficiency and productivity can be enhanced by tracking cycle time and rework hours.

Currently, time is charged out on time cards, and task hours are compared to industrial engineering standards or overhead as agreed upon with the federal government. With the idea of eliminating labor reporting, a team of participants has been assembled and is comprised of representatives from Industrial Engineering, Quality Assurance, Defense Plan

Representative Office, Finance, Defense Contract Audit Agency, Operations, and Management Information Systems. The team – which has a target date of 1 January 1994 for implementation – has the following mission:

"Establish a means for achieving cost savings, through the development and test of a pilot program which eliminates labor reporting. This program will permit universal application while maintaining compliance." (with government standards and requirements)

There are outstanding issues and considerations for resolution as they relate to the Labor Rate Standard (CAS407), the Variance analysis (MIL-STD-1567A), Labor Performance Reporting (MIL-STD- 1567A), and the Costs of Quality Data (MIL-Q-9858A, MOA). 5.

The Hamilton Standard Electronic Manufacturing Center identified the following areas in Design and Production as potential industry-wide problems that should be addressed by industry and government for possible avenues of solution.

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# **SECTION 5**

## **PROBLEM AREAS**

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### **5.1 DESIGN**

#### **Product Development Cycle Compression**

New problems are emerging due to activities throughout the product development processes being compressed and executed in parallel. Material availability from suppliers and internal documentation availability are becoming major constraints. In order to meet the ever shortening schedules, possible premature engineering releases are increasing financial risks.

#### **Extended Product Life Cycle**

The changes in DOD to extend current defense equipment life will increase parts obsolescence. Many of today's current suppliers will either be out of business or will not make the parts because of the expense required to maintain outmoded processes. Many military suppliers, in supporting equipment that is 20 to 25 years old, must choose maintaining a life-of-type stock of obsolete parts, procuring the parts through after-market vendors at high prices, or redesigning and requalifying the new part at extremely high costs.

#### **Requirement Conflicts**

EPA versus MIL-SPEC conflicts are becoming more numerous. For example, EPA requires reduction in volatile organic compounds, such as those found in paints, and the MIL-SPEC calls out for these materials to be used. This type of situation places suppliers in a lose-lose situation. Various anomalies are being discussed at high levels within the government. A recent Section 800 Panel may soon be relieving some of these conflicts. However, a time table is not yet available.

### **MIL-SPEC Component Availability**

The lack of readily available of MIL-SPEC parts artificially increase product costs and lengthen development and manufacturing cycle times. Suppliers often do not wish to stay in this market because demands are for small lot quantities or for specialized parts. Because of the low or no profit margin, DOD contractors have little leverage with component suppliers. Of particular interest is the area of components where commercial industry has accepted plastic components and the military requires ceramic components.

### **5.2 PRODUCTION**

#### **Customer Scheduling Perturbations**

As companies reduce inventory, they face problems delivering products to the customer that had not been scheduled because of the long lead times required for certain components. When customers cancel orders or change the delivery date to a later date, it creates problems with excess inventory that may not be usable on any other product.

#### **Accounting Systems**

Accounting practices by many U.S. firms are still applied that result in excessive inventory as a result of the way overhead is accounted to direct hours charged on the factory floor. Many government regulations also force companies to segregate parts by contract which increases inventory.

#### **Part Marking Removal with New Cleaning Processes**

As new cleaning processes are implemented to eliminate the use of ozone depleting chemicals, a problem has arisen with the new processes removing the part markings.

# **APPENDIX A**

## **TABLE OF ACRONYMS**

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### **ACRONYM DEFINITION**

CFC	Chlorofluorocarbon
CFM	Continuous Flow Manufacturing
CICCP	Continuous Improvement Cost Competitiveness Process
DPRO	Defense Program Representative Office
DTC	Design to Cost
EDI	Electronic Data Interchange
EH&S	Environmental Health and Safety
EPA	Environmental Protection Agency
ESS	Environmental Stress Screening Testing
HSEMC	Hamilton Standard Electronic Manufacturing Center
IPD	Integrated Product Development
IPDS	Integrated Product Design System
LTA	Long Term Agreement
PAFM	Process Analysis for Manufacturability
R&D	Research and Development
SILK	Source Inspection Laptop Kit
SMT	Surface Mount Technology
SPC	Statistical Process Control
SPOU	Supplier Point of Use
WIP	Work in Progress

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## APPENDIX B

### **BMP SURVEY TEAM**

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<b>NAME</b>	<b>ACTIVITY</b>	<b>FUNCTION</b>
<b>Larry Halbig</b> (317) 353-3838	<b>Naval Air Warfare Center</b> Aircraft Division Indianapolis, IN	<b>Team Chairman</b>
<b>Amy Scanlan</b> (703) 271-9055	<b>BMP Representative</b> Washington, DC	<b>Technical Writer</b>
	<b>DESIGN/TEST</b>	
<b>Dave Kuchler</b> (317) 353-7961	<b>Naval Air Warfare Center</b> Aircraft Division Indianapolis, IN	<b>Team Leader</b>
<b>Ronald Cox</b> (812) 854-5251	<b>Crane Division</b> <b>Naval Surface Warfare Center</b> Crane, IN	
<b>John A. Miles</b> (812) 854-5335	<b>Crane Division</b> <b>Naval Surface Warfare Center</b> Crane, IN	
	<b>PRODUCTION/FACILITIES</b>	
<b>Rick James</b> (317) 226-5619	<b>Electronics Manufacturing</b> <b>Productivity Facility</b> Indianapolis, IN	<b>Team Leader</b>
<b>John Greaves</b> (317) 226-5665	<b>Electronics Manufacturing</b> <b>Productivity Facility</b> Indianapolis, IN	
<b>Larry Robertson</b> (812) 854-5336	<b>Crane Division</b> <b>Naval Surface Warfare Center</b> Crane, IN	
	<b>MANAGEMENT/LOGISTICS</b>	
<b>Rick Purcell</b> (703) 271-9055	<b>BMP Representative</b> Washington, DC	<b>Team Leader</b>
<b>Kathryn Ingle</b> (615) 574-9245	<b>Department of Energy</b> <b>Oak Ridge Facilities</b> Oak Ridge, YN	
<b>John Olewnik</b> (215) 897-6684	<b>Naval Industrial Resources</b> Support Activity Philadelphia, PA	

## APPENDIX C

### PROGRAM MANAGER'S WORKSTATION

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The Program Manager's Workstation (PMWS) is a series of expert systems that provide the user with knowledge, insight, and experience on how to manage a program, address technical risk, and find solutions that industry leaders are using to reduce technical risk and improve quality and productivity. This system is divided into four main components: KNOW-HOW, Expert Insight and Improvement (EI<sup>2</sup>), BMP Database, and Best Manufacturing Practices Network (BMP\*NET).

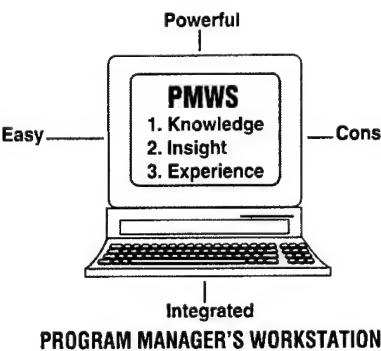
**KNOW-HOW** is an intelligent, automated method that turns "Handbooks" into expert systems, or digitized text. It provides rapid access to information using the expert logic system or fuzzy logic text search. Topics include Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), and the DoD 5000 series documents.

EI<sup>2</sup> contains three current programs - ROLLUP for generating reports on multiple projects; TRASE for detailed software risk assessments based on an SEI model; and TRIMS to conduct a full range of risk assessments throughout the acquisition process so corrective action can be initiated before risks develop into problems. EI<sup>2</sup> programs track key project documentation from concept through completion including goals, responsible personnel, and next action dates for future activities.

The **BMP Database** draws information from industry, government, and academic communities to include documented and proven best practices in design, test, production, facilities, logistics, and management. Each practice in the database has been observed and verified by a team of experienced government engineers. All information gath-

ered from BMP surveys is included in the BMP DATA-BASE, including this survey report.

**BMP\*NET** provides communication between PMWS users. Features include downloading all programs, E-mail, file transfer, help "lines," Special Interest Groups (SIGs), electronic conference rooms and much more. Through BMP\*NET, IBM or compatible PCs and Macintosh computers can run PMWS programs.



To access **BMP\*NET** efficiently, users need a special modem program. This program can be obtained by calling the BMP\*NET using a VT-100/200 terminal emulator set to 8,N,1. Dial (703) 538-7697 for 2400 baud modems and (703) 538-7267 for 9600 baud and above. When asked for a user profile, type: DOWNPC or DOWNMAC <return> as appropriate. This will automatically start a process leading to an X-modem download of our special modem program. You can then call back using this program and access all BMP\*NET functions. Any VT-100/200 type terminal emulator can access BMP\*NET's basic features by entering: VT-100 when asked for a user profile.

The General User account is:

USER PROFILE: BMPNET  
USER I.D.: BMP  
PASSWORD: BMPNET

If you would like your own personal account to receive E-mail, E-mail a request including your name and phone number to either Ernie Renner (BMP Director) or Brian Willoughby (CSC Program Manager). If you encounter problems, please call (703) 538-7253.

# **APPENDIX D**

## **NAVY CENTERS OF EXCELLENCE**

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### **Automated Manufacturing Research Facility**

(301) 975-3414

The Automated Manufacturing Research Facility (AMRF) – a National Center of Excellence – is a research test bed at the National Institute of Standards and Technology located in Gaithersburg, Maryland. The AMRF produces technical results and transfers them to the Navy and industry to solve problems of automated manufacturing. The AMRF supports the technical work required for developing industry standards for automated manufacturing. It is a common ground where industry, academia, and government work together to address pressing national needs for increased quality, greater flexibility, reduced costs, and shorter manufacturing cycle times. These needs drive the adoption of new computer-integrated manufacturing technology in both civilian and defense sectors. The AMRF is meeting the challenge of integrating these technologies into practical, working manufacturing systems.

### **Electronics Manufacturing Productivity Facility**

(317) 226-5607

Located in Indianapolis, Indiana, the Electronics Manufacturing Productivity Facility (EMPF) is a National Center of Excellence established to advance state-of-the-art electronics and to increase productivity in electronics manufacturing. The EMPF works with industry, academia, and government to identify, develop, transfer, and implement innovative electronics manufacturing technologies, processes, and practices. The EMPF conducts applied research, development, and proof-of-concept electronics manufacturing and design technologies, processes, and practices. It also seeks to improve education and training curricula, instruction, and necessary delivery methods. In addition, the EMPF is striving to identify, implement, and promote new electronics manufacturing technologies, processes, materials, and practices that will eliminate or reduce damage to the environment.

### **National Center for Excellence in Metalworking Technology**

(814) 269-2420

The National Center for Excellence in Metalworking Technology (NCEMT) is located in Johnstown, Pennsylvania and is operated by Concurrent Technologies Corporation (CTC), a subsidiary of the University of Pittsburgh Trust. In support of the NCEMT mission, CTC's primary focus includes working with government and industry to develop improved manufacturing technologies including advanced methods, materials, and processes, and transfer-

ring those technologies into industrial applications. CTC maintains capabilities in discrete part design, computerized process analysis and modeling, environmentally compliant manufacturing processes, and the application of advanced information science technologies to product and process integration.

### **Center of Excellence for Composites Manufacturing Technology**

(414) 947-8900

The Center of Excellence for Composites Manufacturing Technology (CECMT), a national resource, is located in Kenosha, Wisconsin. Established as a cooperative effort between government and industry to develop and disseminate this technology, CECMT ensures that robust processes and products using new composites are available to manufacturers. CECMT is operated by the Great Lakes Composites Consortium. It represents a collaborative approach to provide effective advanced composites technology that can be introduced into industrial processes in a timely manner. Fostering manufacturing capabilities for composites manufacturing will enable the U.S. to achieve worldwide prominence in this critical technology.

### **Navy Joining Center**

(614) 486-9423

The Navy Joining Center (NJC) is a Center of Excellence established to provide a national resource for the development of materials joining expertise, deployment of emerging manufacturing technologies, and dissemination of information to Navy contractors, subcontractors, Navy activities, and U.S. industry.

The NJC is located in Columbus, Ohio, and is operated by Edison Welding Institute (EWI), the nation's largest industrial consortium dedicated to materials joining. The NJC combines these resources with an assortment of facilities and demonstrated capabilities from a team of industrial and academic partners. NJC technical activities are divided into three categories - Technology Development, Technology Deployment, and Technology Transfer. Technology Development maintains a goal to complete development quickly to initiate deployment activities in a timely manner. Technology Deployment includes projects for rapid deployment teaming and commercialization of specific technologies. The Technology Transfer department works to disseminate pertinent information on past and current joining technologies both at and above the shop floor.

## APPENDIX E

### ***NEW BEST MANUFACTURING PRACTICES PROGRAM TEMPLATES***

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Since 1985, the BMP Program has applied the templates philosophy with well-documented benefits. Aside from the value of the templates, the templates methodology has proven successful in presenting and organizing technical information. Therefore, the BMP program is continuing this existing “knowledge” base by developing 17 new templates that complement the existing DoD 4245.7-M or Transition from Design to Production templates.

The development of these new templates was based in part on Defense Science Board studies that have identified new technologies and processes that have proven successful in the last few years. Increased benefits could be realized if these activities were made subsets of the existing, compatible templates.

Also, the BMP Survey teams have become experienced in classifying Best Practices and in technology transfer.

The Survey team members, experts in each of their individual fields, determined that data collected, while related to one or more template areas, was not entirely applicable. Therefore, if additional categories were available for Best Practices “mapping,” technology transfer would be enhanced.

Finally, users of the Technical Risk Identification and Mitigation System (TRIMS) found that the program performed extremely well in tracking most key program documentation. However, additional categories – or templates – would allow the system to track all key documentation.

Based on the above identified areas, a core group of activities was identified and added to the “templates baseline.” In addition, TRIMS was modified to allow individual users to add an unlimited number of user-specific categories, templates, and knowledge-based questions.

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## **APPENDIX F**

### **PREVIOUSLY COMPLETED SURVEYS**

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BMP surveys have been conducted at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPNET. Requests for copies of recent survey reports or inquiries regarding the BMPNET may be directed to:

Best Manufacturing Practices Program  
2101 Crystal Plaza Arcade  
Suite 271  
Arlington, VA 22217-5660  
Attn: Mr. Ernie Renner, Director  
Telephone: (703) 696-8483  
FAX: (703) 271-9059

#### **COMPANIES SURVEYED**

Litton Guidance & Control Systems Division Woodland Hills, CA October 1985 and February 1991	Honeywell, Incorporated Undersea Systems Division (Alliant Tech Systems, Inc.) Hopkins, MN January 1986
Texas Instruments Defense Systems & Electronics Group Lewisville, TX May 1986 and November 1991	General Dynamics Pomona Division Pomona, CA August 1986
Harris Corporation Government Support Systems Division Syosset, NY September 1986	IBM Corporation Federal Systems Division Owego, NY October 1986
Control Data Corporation Government Systems Division (Computing Devices International) Minneapolis, MN December 1986 and October 1992	Hughes Aircraft Company Radar Systems Group Los Angeles, CA January 1987
ITT Avionics Division Clifton, NJ September 1987	Rockwell International Corporation Collins Defense Communications Cedar Rapids, IA October 1987
UNISYS Computer Systems Division (Paramax) St. Paul, MN November 1987	Motorola Government Electronics Group Scottsdale, AZ March 1988

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General Dynamics Fort Worth Division Fort Worth, TX May 1988	Texas Instruments Defense Systems & Electronics Group Dallas, TX June 1988
Hughes Aircraft Company Missile Systems Group Tucson, AZ August 1988	Bell Helicopter Textron, Inc. Fort Worth, TX October 1988
Litton Data Systems Division Van Nuys, CA October 1988	GTE C <sup>3</sup> Systems Sector Needham Heights, MA November 1988
McDonnell-Douglas Corporation McDonnell Aircraft Company St. Louis, MO January 1989	Northrop Corporation Aircraft Division Hawthorne, CA March 1989
Litton Applied Technology Division San Jose, CA April 1989	Litton Amecom Division College Park, MD June 1989
Standard Industries LaMirada, CA June 1989	Engineered Circuit Research, Incorporated Milpitas, CA July 1989
Teledyne Industries Incorporated Electronics Division Newbury Park, CA July 1989	Lockheed Aeronautical Systems Company Marietta, GA August 1989
Lockheed Corporation Missile Systems Division Sunnyvale, CA August 1989	Westinghouse Electronic Systems Group Baltimore, MD September 1989
General Electric Naval & Drive Turbine Systems Fitchburg, MA October 1989	Rockwell International Corporation Autonetics Electronics Systems Anaheim, CA November 1989
TRICOR Systems, Incorporated Elgin, IL November 1989	Hughes Aircraft Company Ground Systems Group Fullerton, CA January 1990
TRW Military Electronics and Avionics Division San Diego, CA March 1990	MechTronics of Arizona, Inc. Phoenix, AZ April 1990

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Boeing Aerospace & Electronics Corinth, TX May 1990	Technology Matrix Consortium Traverse City, MI August 1990
Textron Lycoming Stratford, CT November 1990	Norden Systems, Inc. Norwalk, CT May 1991
Naval Avionics Center Indianapolis, IN June 1991	United Electric Controls Watertown, MA June 1991
Kurt Manufacturing Co. Minneapolis, MN July 1991	MagneTek Defense Systems Anaheim, CA August 1991
Raytheon Missile Systems Division Andover, MA August 1991	AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories Greensboro, NC and Whippany, NJ September 1991
Tandem Computers Cupertino, CA January 1992	Charleston Naval Shipyard Charleston, SC April 1992
Conax Florida Corporation St. Petersburg, FL May 1992	Texas Instruments Semiconductor Group Military Products Midland, TX June 1992
Hewlett-Packard Palo Alto Fabrication Center Palo Alto, CA June 1992	Watervliet U.S. Army Arsenal Watervliet, NY July 1992
Digital Equipment Company Enclosures Business Westfield, MA and Maynard, MA August 1992	Naval Aviation Depot Naval Air Station Pensacola, FL November 1992
NASA Marshall Space Flight Center Huntsville, AL January 1993	Naval Aviation Depot Naval Air Station Jacksonville, FL March 1993
Department of Energy- Oak Ridge Facilities Operated by Martin Marietta Energy Systems, Inc. Oak Ridge, TN March 1993	McDonnell Douglas Aerospace Huntington Beach, CA April 1993

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Crane Division  
Naval Surface Warfare Center  
Crane, IN and Louisville, KY  
May 1993

R. J. Reynolds Tobacco Company  
Winston-Salem, NC  
July 1993

Philadelphia Naval Shipyard  
Philadelphia, PA  
June 1993

Crystal Gateway Marriott Hotel  
Arlington, VA  
August 1993

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